Use of Galvanized Rebars in Reinforced Concrete Structures

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Strategies for Corrosion Prevention in RC

• Membranes/paints applied to concrete surface
• Impregnation of concrete mass
• Addition of corrosion inhibitors to concrete mix
• Use of corrosion resisting/clad reinforcement
• Cathodic protection of reinforcement
  - Hot dip galvanized
  - Fusion bonded epoxy coated

GALVANIZED REINFORCEMENT

* First use in USA in 1930’s
  - application by hot-dipping to straight bars or pre-formed sections.
* Zinc alloy coating affords
  - barrier protection and
  - sacrificial protection to base steel.
* Coating provides
  - resistance to pH reduction of concrete
  - higher Cl- tolerance (>2x) than black steel, thus increased service life (4.5x) over black steel.

Carbonation Resistance

Chloride Threshold

For Black Steel:
Assume upper threshold value of 0.4% Cl by mass of cement.

For Galvanized Steel:
Assume lower threshold of 1.0% Cl based on conservative experimental and field data.

Time to Chloride-induced Corrosion

In Marine Concrete:
With 0.35% Cl at concrete surface, 30 mm cover to the reinforcement, D = $1.4 \times 10^{-12}$ m$^2$/s

Black Steel:
Initiate corrosion after 15 years.

Galvanized Steel:
Initiate attack on coating after 44 years—a 3x life extension followed by ongoing protection due to dissolution of coating before attack on base steel.
Galvanized Reinforcing Products

- Straight bars
- Mesh
- Stirrups and ties

The Galvanized Coating:
Metallurgically bonded to base steel

Hard, tough and adherent coating

The Cost of Galvanizing

- May add 30-50% to the cost of the steel.
- Rebar is about 25% of the cost of RC, galvanizing reduces to <10% of cost.
- If the concrete frame is 25-30% of total building costs, the premium reduces to 2-3%.
- Selective galvanizing (eg surface elements) reduces this cost further to < 1% overall.
- Total cost of galvanizing is even less considering the overall value of a project.

National Reinforcing Steel Standards

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<tr>
<th>Country</th>
<th>Standard</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>United States</td>
<td>ASTM A 767</td>
<td>Zinc coated (galvanized) steel bars for concrete reinforcement</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>BS ISO 14657</td>
<td>Zinc coated steel for the reinforcement of concrete</td>
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<tr>
<td>France</td>
<td>NF A 35 925</td>
<td>Hot dip galvanized bars and coils for reinforced concrete</td>
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<td>Italy</td>
<td>UNI 10622</td>
<td>Zinc coated (galvanized) steel bars and wire rods for concrete reinforcement</td>
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<td>India</td>
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<td>Hot dip coatings on structural steel bars for concrete reinforcement specifications</td>
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<tr>
<td>ISO</td>
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</tbody>
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Zinc in Concrete

- A multi-faceted protection to steel rebar
  - both barrier and sacrificial protection
- Provides long-term protection in a variety of exposure conditions
- A small cost premium applies (<1-2%)
- A form of insurance against early corrosion of steel and disruption to the concrete mass

Service Life of Galvanized Reinforcement

Depends on:
- the nature and quality of the concrete,
- the severity of the exposure, and
- the metallurgical characteristics of the coating itself.
Corrosion of Galvanized Coating in Concrete (200x)

- Original coating 180 µm Prior to embedment
- No chloride exposure 164 µm Showing loss of eta layer (20 µm)
- Chloride exposure 110 µm Showing deep attack around zeta phase

Migration of Zinc into Cement Mortar Matrix

Galvanized coating is at left. Zinc corrosion products (ZnO) appear white against the grey, Ca rich cement matrix.

Bond Strength Data

![Graph showing bond strength data with three studies: A, B, C.](image)

- Study A: Strength in Pounds per Square Inch over months of curing.
- Study B: Similar data as Study A.
- Study C: Similar data as Study A.

Load-slip Characteristics

![Graph showing load-slip characteristics with three load levels: 20x, 50x, 1000x.](image)

- 20x: Black Epoxy Coated
- 50x: Epoxy Coated
- 1000x: Epoxy Coated

Applications of Galvanized Reinforcement

- Precast cladding and architectural elements
- Surface exposed structural elements
- Pre fabricated building modules
- Immersed or buried structures or elements
- Coastal, marine and industrial structures
- Transport infrastructure
- High risk structures and prestige construction

Prestige Buildings

- NZ Parliament
- Sydney Opera House
- High Court of Australia
- Australian Parliament
and a few others ...

Precast shell
Decorative egg
Footbridge piers
Tunnel lining

The Bermuda Case Study
RBYC Wharf
Penno's Dock

The Bermuda Experience
Watford Bridge, and all other Bermuda Bridges

and to conclude ...

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