CORROSION RESISTANT

Micro-Alloyed Reinforcement Steel
Corrosion: An annual loss comparable to earthquakes and cyclones!

- The cost of corrosion in India has been estimated to be 2 to 4% of its GNP (Gross National Product).
- The approximate value of the loss is ₹1.5 lakh crore [Indian chapter of NACE International].
- Out of this ₹22,600 crore is incurred in the infrastructure sector.
- With more than 7,000 km of coastline, India’s infrastructure suffers severely from salt water corrosion.
- Pollution and humidity also contribute to metallic corrosion.
Corrosion map of India*

*by CECRI
Corrosion in Reinforcing Steel –
A threat to Infrastructure

How it affects
- Corrosion increases the volume of reinforcement bars, resulting in surface cracking and spoiling of the concrete.
- Scaling of bar surface severely affects bond strength.
- Loss of strength in steel leads to structural failure.

The aggravators
- Long wetness, due to excess atmospheric oxygen from elements like rainfall condensation etc.
- High atmospheric pollution forms soluble iron salts from sulphates, chloride and dust.
- Increased combustion of fossil fuels by vehicles and industrialization, thus increasing atmospheric sulphur dioxide.
- Coastal effect, from high concentration of chlorides present in coastal areas.
- Poor concreting, honeycombed surface and porosity.

Types of Corrosion
**Uniform Corrosion:** When the structure is directly exposed to aggressive marine or industrial atmospheric conditions.

**Pitting Corrosion:** When chloride concentration is high enough to destroy passivity at weak points on metal surface.

**Stress Corrosion:** In pre-stress concrete where steel is initially held in tension, stress corrosion cracking occurs in a specific environment for a given alloy.
Corrosion of metal is natural and rapid in areas with high humidity, seacoasts, high salinity, etc. This menace can destroy even the toughest buildings, bridges, dams, chimneys, plants, ports etc. The corrosion process can be broadly explained as follows:

**Carbonation:** Hydration of cement tends to make the poured solution of concrete alkaline (pH value typically within 12.5 - 13.6). Here, reinforcing steel passivates and forms a corrosion-preventing oxide layer over the surface. Concrete's porosity enables corrosive chemical agents (moisture, water, chloride etc.) to enter and cause further reactions between atmospheric CO₂ (Carbon dioxide) and existing alkalis. Over the time, the pH values decreases below 10, causing loss of alkalinity and decaying the oxide layer of the steel. Once the layer is broken, the electromechanical reaction of corrosion starts.

**Electrochemical process:** It involves the transfer of ions. Electrochemical corrosion requires an anode, a cathode an electrolyte and an electronic circuit. The concrete media containing moisture and mainly Co(OH)₂ is an electrolyte conducting an electric current by ionic flow. The anodic and reduction reaction forms Ferric Hydroxide which dehydrates to form Ferric Oxide, commonly known as rust.

**Effect of re-bar corrosion on concrete** Rust has five times more volume than steel. This causes tensile stresses which fractures the concrete around the reinforcement. As cracks grow, concrete permeability increases allowing greater access of oxygen, moisture and chlorides to the steel. The cracks cause significant loss of bond between the steel and concrete. In extreme cases, failure of reinforced concrete members also occurs.
Protecting the steel inside concrete against corrosion

There have been several efforts to control corrosion viz: Fusion-Bonded Epoxy Coating, Hot Dip Galvanising, Zinc Coating through Cold Process - but these have failed in practical usage.

Epoxy coated Re-bars

The first logical corrosion protection that was tried, on the reinforcing steel in concrete, was the existing range of paints. These types of Re-bars offer limited corrosion resistance and have proven not to be effective in the long run, owing to several application-related issues.

The major problems

- Tiny pin holes like structure known as “Holidays” develops on the coated surface. Corrosion starts at these “Holiday” points.
- The coating is easily damaged during transportation, forming and placing the bars in forms.
- The coating reduces the bond strength.
- The coating is fragile, thus possesses limited life.
- High chloride concentrations makes the coating brittle, causing de-lamination from steel surface.
- Coating tends to break at the tension section exposing the base metal during bending, re-bending, cutting and concrete-pouring at site leading to faster corrosion.
- The coating looses stability beyond 2000°C, making structures less fire-resistant.
- The coating gets damaged at the point of welding and base metal gets exposed which in turn becomes the weak point of a structure.
- The cost of epoxy coating is very high.

![Diagram showing the effects of Epoxy coated Re-bars]

- New Coating
- Imperfection - Damage
- Disbondment At Yard
- Adherence Loss In Chloride - Free Concrete
- After Chloride Arrival
- Corrosion Products
- Low Ph
- Holidays corroding the coating underneath

![Knife adhesion test after 4 weeks of exposure]
**Zinc-coated Re-bars**

Zinc-coated Re-bar give reasonably good corrosion resistance but has been proved not to be effective in the long run.

**The major problems**

- Silicon and phosphorous content in reinforcing steel severely affects galvanized coating. High silicon concentration causes very thick and brittle coating which peels off under mechanical stress.
- Cracks caused from Bending or Re-bending of galvanized Re-bar during fabrication at site, destroys galvanizing layer exposing base metal.
- Re-bar galvanized by hot-dip process do not provide enough concrete adhesion and Bond Strength.
- Re-bar needs to be galvanized in a factory which amounts to their size restriction.
- The cost of Zinc coating is very high in comparison to other measures.
- Zinc coated Re-bar cannot be used in combination of uncoated bars.
- Galvanizing bent Re-bar causes strain and ageing. Subsequently surface cracks develop on the coated layer at these places.
- Welding of Zinc coated Re-bar is not possible.
Microalloyed Re-bar – The Right Solution

The right anti-corrosion solution is a metallurgical route-controlled composition alloy with anti-corrosion elements and improved production process – Microalloyed (MA) Re-bars, manufactured by Shyam Steel as Shyam CRS TMT Re-bars.

In the Electric Arc Furnace, corrosion resistant elements like copper, chromium and phosphorous are added to the molten steel, while carbon and sulphur is reduced further through refining and deslagging. The microalloyed molten steel is then casted into billets and rolled in a controlled quenching and tempering process, imparting corrosion resistant properties far exceeding those of epoxy or zinc coated Re-bars.

The major advantages

- In such Re-bars, corrosion resistance is improved while retaining strength, toughness, ductility and formability.
- Higher strength of the Re-bars result in lower tonnage requirement, thus reducing construction cost.
- It is not a coated material. So it is unaffected by transport, handling or concrete pouring, thus eradicating touch-ups.

<table>
<thead>
<tr>
<th>Description</th>
<th>Shyam Re-bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2% Proof Stress (N/mm², min)</td>
<td>540</td>
</tr>
<tr>
<td>Ultimate Tensile Strength (N/mm², min)</td>
<td>620</td>
</tr>
<tr>
<td>% Elongation (min)</td>
<td>18</td>
</tr>
<tr>
<td>Bend</td>
<td>3D to 4D</td>
</tr>
<tr>
<td>Re-bend</td>
<td>4D to 6D</td>
</tr>
<tr>
<td>C (%max)</td>
<td>0.150</td>
</tr>
<tr>
<td>Mn (%max)</td>
<td>1.500</td>
</tr>
<tr>
<td>Si (% max)</td>
<td>0.035</td>
</tr>
<tr>
<td>P (% max)</td>
<td>0.100</td>
</tr>
<tr>
<td>CE (%max)</td>
<td>0.500</td>
</tr>
<tr>
<td>CRE (% min)</td>
<td>0.500</td>
</tr>
</tbody>
</table>
## Performance Comparison of Re-bars

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Zinc Coated</th>
<th>Epoxy Coated</th>
<th>Microalloyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond Strength to Concrete</td>
<td>Good</td>
<td>Poor</td>
<td>Excellent</td>
</tr>
<tr>
<td>UV Resistance</td>
<td>Excellent</td>
<td>Approximately 3 months, depends on the Epoxy paint</td>
<td>No adverse effect</td>
</tr>
<tr>
<td>Uniformity of Coating Thickness</td>
<td>May vary</td>
<td>May vary</td>
<td>No surface coating</td>
</tr>
<tr>
<td>Can be Dragged on Ground</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Bond between Base Metal &amp; Coating</td>
<td>Good</td>
<td>Poor compared to Galvanizing</td>
<td>No surface coating</td>
</tr>
<tr>
<td>Damage of coating after fabrication after coating application</td>
<td>Coating may get damaged locally but with no adverse effects</td>
<td>Coating may get damaged that may lead to crevice corrosion of Re-bar</td>
<td>No adverse effect since there is no coating</td>
</tr>
<tr>
<td>Construction Damage</td>
<td>Bending, rebending &amp; cutting may cause cracks on coated surface</td>
<td>Bending, rebending &amp; cutting may cause cracks on coated surface</td>
<td>No adverse effect since there is no coating</td>
</tr>
<tr>
<td>Touched up Paint after fabrication</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Problems In storage / handling at factory or job site</td>
<td>Additional precaution to prevent ‘white rusting’</td>
<td>Extensive</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: Indian Institute of Technology, Kharagpur

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### Corrosion of re-bars in industrial atmosphere

![Graph showing corrosion of TMT and CRS re-bars over time](chart.png)
CRS TMT Re-bars – Facts in favour

Worldwide demand for Microalloyed Re-bars generate majorly from industries like Power, Oil and Gas extraction, Road & Bridge construction and Port development. This is due to their improved strength, ductility, corrosion properties as well as increased toughness. These Re-bars offer the following major advantages:

- Increase in the lifespan of the structure.
- CRS TMT have intrinsically improved corrosion resistance as compared to other methods of combating corrosion.
- High yield strength coupled with good ductility and bendability.
- No extra precaution in handling and storage required.
- No extra precaution in Bending and Re-bending needed.
- Due to lower carbon equivalent, weldability is far superior than conventional Re-bars.
- Can perform better in case of earthquake and fire.

International projects where similar Re-bars have been used

- Australian Centre for Contemporary Art
- John Deere World Headquarters, Moline Illinois
- U.S Steel Tower, Pittsburgh
- Antioch River Bridge, California
- White Chick River Bridge, USA
- Foote Mineral Co. Bridge, Cleveland County

Indian projects where similar re-bars have been used

- Vizag Port
- Alwarpet Flyover, Chennai
- Krishnapatman Port
- Cochin Port
- Kakinada Basin
- Mangalore Sez
- UP Jal Nigam
- Delhi JAL Board
Shyam CRS TMT Re-bars – A proud presence throughout India

Shyam CRS TMT Re-bars have been used in projects like

- Kerala Water Board Project
- NTPL Tuticorin TPC, Tamilnadu
- Paradip Port National Highway, NHAI
- Haldia Port National Highway, NHAI
- Indian Oil Corporation Ltd, Haldia
- Kandla Port Trust
- JNPT IOCL Terminal
- Reliance KG Basin
- Mahagenco Bhusawal TPS Expansion
- Apagenco Krishnapatnam TPS

Shyam CRS TMT Re-bars are ideal for

- Oil & Gas Exploration Sites
- Dams & Bridges
- Highways & Flyovers Construction
- Ports & Jetties
- Thermal & Hydel Power Station
- Industrial Structures
- Hazardous Area Construction
Shyam CRS TMT Re-bars – thoroughly tested

Shyam CRS TMT Re-bars and similar microalloyed Re-bars have been tested in a number of premium research laboratories of India viz. • Indian Institute of Technology, Kharagpur • National Test House, Kolkata • Regional Testing Centre, Kolkata • National Metallurgical Laboratory, Jamshedpur • Structural / Engineering Research Centre, Chennai • Central Building Research Institute, Roorkee etc.

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Non CRS TMT Re-bars</th>
<th>CRS TMT Re-bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potentio Dynamic Test</td>
<td>1.0</td>
<td>2.35</td>
</tr>
<tr>
<td>Salt Spray Test</td>
<td>1.0</td>
<td>1.59</td>
</tr>
<tr>
<td>Sulphur-Dioxide Test</td>
<td>1.0</td>
<td>1.68</td>
</tr>
<tr>
<td>Alternate Immersion Test</td>
<td>1.0</td>
<td>1.92</td>
</tr>
</tbody>
</table>
Customer Testimony

- Indian Oil Corporation Ltd.
- Tokyo Engineering Consultants Co. Ltd.
- Reliance Industries Ltd.
- Nagpur Municipal Corporation
- MSRDC
- CIDCO
A Proud Presence

Sectors
- Roads and Highways
- Nuclear, Thermal and Hydel power
- Railways
- Metro Rail
- Defence
- Air and Sea ports
- Oil exploration and refinery

Projects of National Pride
- Vidyasagar Setu
- Reliance KG Basin
- Panipath Elevated Expressway
- P V Narshima Rao Expressway
- Hyderabad International Airport
- Bangalore International Airport
- Tau Devilal Power Plant
- Rosa Thermal Power Plant
- North-South and East-West Corridor Project
- NHAI
- Kothagudem Power Plant ...

Customers of National Repute
- L&T
- Simplex
- Gammon
- Punj Lloyd
- HCC
- GMR
- Lanco
- Reliance
- IVRCL
- ITD
- Soma
- GVK
- BGR Energy
- NCC
- IJM ...

Durgapur Plant
Shyam Steel at a glance

Established 1953

Plants
- Integrated Steel Plants (ISP) at Durgapur, West Bengal
- DRI, Ferro and Cement Plant at Mejia, West Bengal
- Speciality Rolling mills at Howrah, West Bengal

Head Office Sector V, Salt Lake, West Bengal

Branches 13 Across India

Products
- TMT
- CRS
- EQR

Quality Ten-point quality control system

Certificates
- ISO 9001
- OHSAS 18001
- ISO 14001