BRIDGE AND HIGHWAY REINFORCING STEEL SOLUTIONS

CORROSION RESISTANT • HIGH-STRENGTH • REDUCED CONGESTION
Service Life and Lower Life Cycle Costs
ChromX Concrete Reinforcing Steels

ChromX concrete reinforcing steels provide high strength with varying levels of corrosion resistance, so designers can utilize the high strength efficiencies and best match the corrosion protection requirements of the structure.

The service life (the time to first repair) is driven by the corrosion of the reinforcing steel. Reinforcing steel corrosion begins when the chloride concentration at the steel surface reaches the critical chloride threshold (CT) value of that steel. The corrosion continues at the corrosion rate (CR) of the steel, eventually causing cracking and spalling of the concrete and deterioration of the structure.

All ChromX rebar has substantially higher CT levels than black bar. For example, ChromX 9100’s CT value is four times that of black bar and twice that of galvanized bar. In addition, the CR value for ChromX rebar is one-third that of black bar. These higher CT and lower CR values are the reason that ChromX products extend the structure’s service life, saving repair and maintenance costs, resulting in lower life cycle costs compared to other steel reinforcing products.

Additionally, perfectly applied epoxy coating performs well in laboratory tests, but field studies prove that the coating does not survive field handling and installation, and therefore provides little to no protection.

Comparison of Service Life and Life Cycle Cost Analysis (LCCA) in Bridge Decks

<table>
<thead>
<tr>
<th>Reinforcing Bar</th>
<th>Service Life</th>
<th>Est. Initial Cost</th>
<th>50-yr. LCCA</th>
<th>75-yr. LCCA</th>
<th>100-yr. LCCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bar</td>
<td>25</td>
<td>$7.32</td>
<td>$16.07</td>
<td>$18.77</td>
<td>$19.30</td>
</tr>
<tr>
<td>Epoxy Coated</td>
<td>34</td>
<td>$10.08</td>
<td>$16.23</td>
<td>$17.45</td>
<td>$18.50</td>
</tr>
<tr>
<td>Galvanized</td>
<td>55</td>
<td>$13.68</td>
<td>$13.68</td>
<td>$16.38</td>
<td>$16.91</td>
</tr>
<tr>
<td>ChromX 2100</td>
<td>40</td>
<td>$9.24</td>
<td>$12.36</td>
<td>$15.06</td>
<td>$15.60</td>
</tr>
<tr>
<td>ChromX 4100</td>
<td>61</td>
<td>$9.72</td>
<td>$9.72</td>
<td>$11.09</td>
<td>$12.28</td>
</tr>
<tr>
<td>ChromX 4100 w/CNI</td>
<td>&gt;100</td>
<td>$10.03</td>
<td>$10.03</td>
<td>$10.03</td>
<td>$10.03</td>
</tr>
<tr>
<td>ChromX 9100</td>
<td>&gt;100</td>
<td>$14.52</td>
<td>$14.52</td>
<td>$14.52</td>
<td>$14.52</td>
</tr>
<tr>
<td>Stainless Steel (UNS 32304)</td>
<td>&gt;100</td>
<td>$25.32</td>
<td>$25.32</td>
<td>$25.32</td>
<td>$25.32</td>
</tr>
</tbody>
</table>

1 Service lives estimated based on CT values determined in Critical Chloride Corrosion Threshold for Galvanized Reinforcing Bars, David Darwin et al., Univ. of Kansas Center for Research, Inc. (Dec. 2007), as well as CT and CR values, and STADIUM® software modeling for a concrete bridge deck with 1.5 in. (37.5 mm) Bridge Mix LP concrete cover according to Reinforcing Steel Comparative Durability Assessment and 100 Year Service Life, Tourney Consulting Group, LLC (June 2016).

2 Estimated net present value (NPV) per square foot of the total life cycle costs of the bridge deck, assuming $150 per square foot repair costs every 15 years after year of initial repair.

3 Based on chloride threshold data from Tourney Consulting Group, LLC testing of ChromX 2100 alloy (2017).

4 Adding 2 gallons of calcium nitrite (CNI) as a concrete additive at an estimated cost of $12 per cubic yard has been shown to further enhance ChromX 4100’s corrosion performance.
Areas of the same bridge have different corrosion protection requirements. The full ChromX product line (9100, 4100 and 2100) allows designers to select the product that best fits the application.

- **Atmospheric Zone.** The atmosphere to which the bridge is exposed varies widely with the location of the bridge. Inland bridge atmosphere is relatively benign and therefore raises low to no corrosion concern, while bridges over or near seawater have higher corrosion potential. Atmospheric bridge members for inland bridges can use ChromX 2100, while bridges exposed to seawater use ChromX 4100 or 9100.

- **Deck and Deicing Salt Spray Zone.** ChromX 9100 should be used in the areas of a bridge where deicing salts are used.

- **Splash Zone.** The splash zone is a severe corrosive environment requiring ChromX 9100’s corrosion protection.

- **Submerged Zone.** Designers should consider ChromX 9100 or 4100 for the submerged zone, which is less corrosive than the splash zone.

- **Embedded Zone.** There is usually low corrosion potential in the embedded zone depending on the composition and contents of the soil, therefore ChromX 2100 is a good choice.

**Savings Realized Upon First Repair of ECR**

Significant savings are realized upon first repair and accumulate throughout the service life.

<table>
<thead>
<tr>
<th>Cumulative Costs for Reinforcement &amp; Repair ($/sq ft)</th>
<th>In-Place Costs</th>
<th>Repair Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChromX 9100 and 4100 vs. ECR (Deicing Bridge Deck)</td>
<td>In-Place Costs</td>
<td>Repair Costs</td>
</tr>
<tr>
<td>ChromX 9100, No repairs for 100 yrs</td>
<td>No repairs for 60 yrs</td>
<td>Repair by 34th year</td>
</tr>
</tbody>
</table>

On average, rebar accounts for only 1% to 4% of the total cost of construction, yet this relatively small cost item ultimately determines the operational service life of the multi-million dollar structure.

In addition, repair costs easily overshadow minor differences in initial construction costs, so using ChromX rebar can greatly reduce the overall cost of a structure.
High Strength Bridge Designs
ChromX Concrete Reinforcing Steels

High Strength Tensile Properties

<table>
<thead>
<tr>
<th>Spec Grade</th>
<th>2100</th>
<th>4100</th>
<th>9100</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A1035 CL</td>
<td>ASTM A1035 CM</td>
<td>ASTM A1035 CS AASHTO/M334</td>
<td></td>
</tr>
<tr>
<td>Tensile Strength, min, psi</td>
<td>150,000</td>
<td>150,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Yield Strength (0.2% offset) min, psi</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
</tr>
</tbody>
</table>

Elongation in 8 in. [200 mm] min

<table>
<thead>
<tr>
<th>Bar Designation</th>
<th>No. 3 through 11 [10 through 36]</th>
<th>14, 18 [43, 57]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Stress vs. Strain Curves of ChromX vs. Black Bar

Maximum Tensile Strengths (ksi) of Reinforcement for Use in Bridge Designs

<table>
<thead>
<tr>
<th>Seismic Zones</th>
<th>Foundations</th>
<th>Columns / Walls</th>
<th>Decks</th>
<th>Beams / Girders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abutments</td>
<td>Piles</td>
<td>Pile Caps</td>
<td>Vertical</td>
</tr>
<tr>
<td>Zone 1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Zone 2</td>
<td>100(1)</td>
<td>100(1)</td>
<td>100(1)</td>
<td>100(1)</td>
</tr>
<tr>
<td>Zone 3</td>
<td>100(1)</td>
<td>100(1)</td>
<td>100(1)</td>
<td>N/R(5)</td>
</tr>
<tr>
<td>Zone 4</td>
<td>100(1)</td>
<td>100(1)</td>
<td>100(1)</td>
<td>N/R(5)</td>
</tr>
</tbody>
</table>

Designers can use the high strength Grade 100 properties of all three ChromX steels to efficiently design and construct better bridges, resulting in the lowest life cycle costs.

2Yield strength limited to 60 ksi for shear friction calculation.
3Yield strength of transverse reinforcement limited to 60 ksi for shear strength computations.
4Required shear strength must be calculated per Articles 8.3.2 and 8.6.1 and minimum shear reinforcement must be provided per Article 8.6.5 of the AASHTO Guide Specifications for LRFD Bridge Design.
5Not recommended. Concrete reinforcing steel used must meet ASTM A706 seismic requirements.
Examples of Efficient Bridge Design Techniques

Design, Installation, and Condition Assessment of a Concrete Bridge Deck Constructed with ASTM A1035 CS No. 4 Bars
by Virginia Center for Transportation Innovation & Research

- Using higher yield stress from ChromX 9100 to replace No.5 bars with No. 4 bars
- Saving 23% by weight of steel on the deck
- Reducing bar congestion, especially near the traffic barrier bridge splice
- Saving 23% in material cost

Reference:
Final Report VCTR 15-R10
A. Salomon; C. Moen (June 2017)

Structural Design Guidelines for Concrete Bridge Decks Using High Strength and Corrosion Resistant Reinforcing (CRR) Bars
by Virginia Center for Transportation Innovation & Research

- Reducing steel weight by 36%
- Thinning clear cover from 2.5 to 2.0 inches
- Identifying significant savings in construction costs and time
- Improving serviceability

Reference:
Final Report VCTR 15-R10
(October 2014)

Alternative to Post-Tensioning for Pier Cap by eConstruct.USA, LLC

- Simplifying construction steps
- Reducing pier cap weight
- Reducing concrete
- Saving on reinforcement and post-tensioning costs

Reference:
MMFX Steel Alternative to Post-Tensioning for Pier Cap, eConstruct.USA, LLC (2015)
Bridge Applications

ChromX Steel Installations in North America and the Caribbean

- Alabama
- Alberta
- Arizona
- Bahamas
- British Columbia
- California
- Colorado
- Connecticut
- Delaware
- Florida
- Georgia
- Idaho
- Indiana
- Iowa
- Kentucky
- Maine
- Manitoba
- Maryland
- Massachusetts
- Michigan
- Mississippi
- Missouri
- Montana
- New Brunswick
- New Hampshire
- New Mexico
- New York
- North Carolina
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- Puerto Rico
- Saskatchewan
- South Carolina
- Tennessee
- Texas
- Utah
- Vermont
- Virginia
- Washington
- West Virginia

Dowel Bar Applications

ChromX Uncoated Corrosion Resistant Steel Pavement Dowel and Tie Bars

ChromX dowel bars and tie bars extend roadway service life

Smooth round pavement dowels serve as load transfer devices (LTDs) at transverse joints in plain jointed concrete pavement (PJCP). Dowel bars are generally 18” long by 1 ¼” or 1 ½” in diameter, spaced 12” across the transverse joints, depending on pavement thickness and traffic considerations. The placement of dowel bars is made by using either dowel bar baskets prior to pouring concrete or dowel bar inserter equipment as part of a retrofit or repair project.
Specifications & Design Codes

For specifications, visit cmc.com/chromx.

Qualified Fabricators

We recommend partnering with a qualified, full service CRSI fabricator for fabrication of your ChromX steel products.

CMC Rebar operates state-of-the-art fabrication facilities at locations throughout the United States. At each of our facilities, we have the estimating, detailing and fabricating experience to manage any project, regardless of size or schedule demands. All of our CMC Rebar plants are CRSI certified, ensuring that ChromX steel products and services adhere to the highest quality and all industry standards.

Contact CMC Rebar to discuss your ChromX project today!

CMC Rebar
803.254.4660, Eastern U.S.
512.282.8820, Central U.S.
909.803.1500, Western U.S. & Hawaii
www.cmc.com

Technology

ChromX steel is specially formulated out of low carbon, chromium alloy steel that lacks the typical grain boundaries of carbides and ferrites found in conventional carbon steel. Steel made using MMFx® nanotechnology significantly minimizes the formation of corrosive currents that are inherent in carbon steel bars, thus reducing the driving force behind corrosion. The resulting steel bar is strong yet ductile and provides up to five times more corrosion resistance than conventional carbon steel without the use of coatings.

Eligible for LEED credits in
Materials and Resources
Innovation in Design
About ChromX

MMFX® Technologies, a Commercial Metals Company, is a steel company dedicated to applying innovative steel technologies to multiple product lines. With its steel production capability within CMC, Cascade Steel, OEM manufacturers and global licensees, MMFX delivers solutions to problems faced by steel consumers. As a dependable technical resource, MMFX continuously strives to deliver unmatched value to its customers through the application of advanced nano steel technology.

MMFX has removed long-standing limitations faced by structural engineers and the construction industry by introducing its ChromX brand high strength concrete reinforcing steel products with varying levels of corrosion resistance, so designers can utilize the high strength efficiencies and best match the corrosion protection requirements of a given project.

ChromX 9100 Series (formerly MMFX2®) concrete reinforcing steels can be specified as ASTM A1035 CS either Grade 100 or 120. This chromium steel provides high corrosion protection for severe corrosive environments caused by seawater, aggressive soils and deicing salts. Designers can meet 100-year service life requirements called for on many infrastructure projects by specifying ChromX 9100.

ChromX 4100 Series (ASTM A1035 CM Grade 100 or 120) offers the same high strength benefits with a medium level of corrosion resistance for projects requiring 40 to 60 years of service life, depending on the specific application and design.

ChromX 2100 Series (ASTM A1035 CL Grade 100 or 120) is a low cost product ideal for construction projects in which high strength designs reduce the amount of steel used, improving constructability, and reducing construction time and costs for the owner.

By specifying ASTM A1035 CS, CM or CL, designers can take advantage of the high strength efficiencies and match the appropriate corrosion resistance for the targeted service life of the structure utilizing the CSI Etabs software to incorporate the design guidelines for ASTM A1035 properties.

Commercial Metals Company and its subsidiaries manufacture, recycle and market steel and metal products, related materials and services through a network of facilities that includes eight electric arc furnace (“EAF”) mini mills, two EAF micro mills, a rerolling mill, steel fabrication and processing plants, construction-related product warehouses, and metal recycling facilities in the United States and Poland.

MMFX Technologies, A Commercial Metals Company, with its industry partners and OEM manufacturers, continues to develop and deliver additional steel products utilizing the MMFX nanotechnology to the market such as threaded bar, anchor bolts and couplers.

ChromX products are marketed and sold globally through CMC steel mills, OEM manufacturers and regional licensees.

To Place An Order

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