Reducing Cost and Solving Problems in BRIDGES AND HIGHWAYS
ChrömX 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.

The CT of ChrömX 9100 is 4X that of Black Bar and twice that of ChrömX 4100. In addition, both ChrömX 9100 and 4100 have a CR value of 1/3 that of Black Bar. These higher CT and lower CR values are the reason the ChrömX products extend the structure’s service life, saving repair and maintenance costs, resulting in lower life cycle costs compared to other steel reinforcing products.

**Comparative Table 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-Year LCCA**</th>
<th>75-Year LCCA**</th>
<th>100-Year LCCA**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bar</td>
<td>25</td>
<td>$7.92</td>
<td>$21.22</td>
<td>$27.39</td>
<td>$30.25</td>
</tr>
<tr>
<td>Epoxy Coated</td>
<td>34</td>
<td>$10.62</td>
<td>$21.18</td>
<td>$26.08</td>
<td>$27.44</td>
</tr>
<tr>
<td>Galvanized</td>
<td>50</td>
<td>$12.70</td>
<td>$16.87</td>
<td>$19.71</td>
<td>$22.97</td>
</tr>
<tr>
<td>ChrömX 4100</td>
<td>61</td>
<td>$11.16</td>
<td>$11.16</td>
<td>$16.45</td>
<td>$17.91</td>
</tr>
<tr>
<td>ChrömX 4100 w/ CNI***</td>
<td>&gt;100</td>
<td>$13.36</td>
<td>$13.36</td>
<td>$13.36</td>
<td>$13.36</td>
</tr>
<tr>
<td>ChrömX 9100</td>
<td>&gt;100</td>
<td>$15.06</td>
<td>$15.06</td>
<td>$15.06</td>
<td>$15.06</td>
</tr>
<tr>
<td>Stainless (UNS S32304)</td>
<td>&gt;100</td>
<td>$25.56</td>
<td>$25.56</td>
<td>$25.56</td>
<td>$25.56</td>
</tr>
</tbody>
</table>

* 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 Modeling for a concrete bridge deck with 1.5 in. (37.5 mm) Bridge Mix LP concrete cover according to Reinforcing Steel Comparative Durability Case Studies and 100 Year Service Life Cost Analysis Report, Tourney Consulting Group, LLC 2015.

** Estimated net present value (NPV) per square foot of the total life cycle costs of the bridge deck.

*** Adding 2 gallons of calcium nitrite as a concrete additive at an estimated cost of $2.20 per square foot has been shown to further enhance ChrömX 4100’s corrosion performance.

Chart Notes:
2. ECR Chloride Threshold set at black bar’s CT. 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.
3. ChrömX 4100 comparison figure based on Tourney Consulting Group, LLC, Reinforcing Steel Comparative Durability Case Studies and 100 Year Service Life Cost Analysis Report, Tourney Consulting Group, LLC 2015.
Areas of the same bridge have different corrosion protection requirements. The full ChrōmX product line (9100, 4100 and 2100) allows all 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 ChrōmX 2100, while bridges exposed to seawater should consider using ChrōmX 4100 or 9100.

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

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

- **Submerged Zone.** While actually less corrosive than the splash zone, designers should consider ChrōmX 9100 or 4100 for the submerged zone.

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

**Savings Realized Upon First Repair**

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

![Graph showing savings realized upon first repair](image)
High Strength Bridge Designs

With ChrōmX Concrete Reinforcing Steels

Use the high strength Grade 100 properties of all three ChrōmX steels to efficiently design and construct better bridges, reducing upfront construction costs.

High Strength Tensile Properties

<table>
<thead>
<tr>
<th>ChrōmX</th>
<th>2100</th>
<th>4100</th>
<th>9100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification</td>
<td>ASTM A1035 CL</td>
<td>ASTM A1035 CM</td>
<td>ASTM A1035 CS</td>
</tr>
<tr>
<td>Grade</td>
<td>100 [690]</td>
<td>100 [690]</td>
<td>100 [690]</td>
</tr>
<tr>
<td>Tensile Strength, min, psi [MPa]</td>
<td>130,000 [900]</td>
<td>150,000 [1030]</td>
<td>150,000 [1030]</td>
</tr>
<tr>
<td>Yield Strength (0.2% offset) min, psi [MPa]</td>
<td>100,000 [690]</td>
<td>100,000 [690]</td>
<td>100,000 [690]</td>
</tr>
<tr>
<td>Elongation in 8 in. [200 mm], min</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Bar Designation No. 3 through 11 [10 through 36] 14, 18 [43,57]</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Stress vs. Strain Curves for ASTM A1035, CS, CM & CL

ACI ITG-6R-10
“Design Guide for the Use of ASTM A1035/A1035M Grade 100 (690 MPa) Steel Bars for Structural Concrete”

ICC-ES AC429 & ESR 2107
“Acceptance Criteria for High-Strength Steel Reinforcing Bars”

AASHTO LRFD Bridge Specification
“Bridge Design for the Use of ASTM A1035/A1035M Grade 100 (690 MPa) Steel Bars for Bridge Structures”
Specifications and Codes

- ASTM A1035 CS, CM, CL Grades 100 and 120
- AASHTO MP18
- AASHTO LRFD Bridge Design Specification
- ACI 318
- ACI ITG-6R-10 Design Guide
- ICC-ES Evaluation Report ESR-2107
- ICC-ES Acceptance Criteria AC429
- USAGE Unified Facilities Guide Specification

Usage Unified Facilities Guide Specification

- Tested and Accepted
  - Alabama
  - Alberta
  - Arizona
  - Colorado
  - Connecticut
  - Delaware
  - Florida
  - Georgia
  - Idaho
  - Indiana
  - Iowa
  - Kentucky
  - Massachusetts
  - Maine
  - Manitoba
  - Michigan
  - New Hampshire
  - New Mexico
  - North Carolina
  - Ohio
  - Oklahoma
  - Pennsylvania
  - South Carolina
  - Texas
  - Virginia
  - Washington
  - Utah

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**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>Breams / 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(3)</td>
<td>100(3)</td>
<td>100(3)</td>
<td>100(4)</td>
</tr>
<tr>
<td>Zone 3</td>
<td>100(3)</td>
<td>100(3)</td>
<td>100(3)</td>
<td>N(5)</td>
</tr>
<tr>
<td>Zone 4</td>
<td>100(3)</td>
<td>100(3)</td>
<td>100(3)</td>
<td>N(5)</td>
</tr>
</tbody>
</table>


(2) Yield strength limited to 60 ksi for shear-friction calculation.

(3) Yield strength of transverse reinforcement limited to 60 ksi for shear strength computations.

(4) Required 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.

(5) Not recommended. Concrete reinforcing steel used must meet ASTM A706 seismic requirements.

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**Examples of Efficient Bridge Design Techniques**

**Structural Design Guidelines for Concrete Bridge Decks Using 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 VCTIR 15-R10 (October 2014)

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

- Without ChrōmX
- With ChrōmX

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

Reference: MMFX Steel Alternative to Post-Tensioning for Pier Cap, eConstruct.USA, LLC (2015)
Uncoated Corrosion Resistant Steel Pavement
Dowel and Tie Bars

ChrōmX brand dowel bars and tie bars are available.

Smooth round pavement dowels serve as load transfer devices (LTD’s) 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 either using: dowel bar baskets prior to pouring concrete or dowel bar inserter equipment as part of a retrofit or repair project.
The MMFX Story

MMFX® Technologies Corporation is a global specialty steel company dedicated to applying innovative steel technologies to multiple product lines. With its steel production partners, OEM manufacturers and industry leaders, 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.

The MMFX Technology Difference

Over 100,000 tons of steel placed in concrete

MMFX has removed long-standing limitations faced by structural engineers and the construction industry by introducing its ChrōmX 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.

ChrōmX 9000 (formerly MMFX®) 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 ChrōmX 9000.

ChrōmX 4000 (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.

ChrōmX 2000 (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

In conjunction with its industry partners and OEM manufacturers, MMFX continues to develop and deliver additional steel products utilizing the MMFX nanotechnology to the market, such as thread bar, anchor bolts, and couplers.

MMFX products are marketed and sold globally through MMFX’s operating subsidiaries (MMFX Steel Corporation of America and MMFX Steel DMCC), as well as OEM manufacturers and regional licensees.
How to Order

For specific product related questions about ChrōmX or to place an order, we invite you to contact us at (866) 466-7878 or one of our partners listed below.

STOCKING DISTRIBUTORS

- Cascade Steel Rolling Mills (Licensee)
  (503) 472-4181, (800) 611-2776, www.cascadesteel.com
- Construction Materials Group dba
  Rockingham Steel/Transcon Supply
  (540) 433-3000, www.concrete4u.com
- Metal Partners
  (973) 986-9876, www.metalpartnersrebar.com
- Steelcon Supply
  (304) 255-1416, West Virginia • (407) 209-9207, Florida
  www.steelconsupply.com
- Stuart Building Products
  (954) 978-8900, Florida
  stacy.mower@stuartbuildingproducts.com
- Williams Form Engineering
  (503) 285-4548, www.williamsform.com

QUALIFIED DISTRIBUTORS

- Adelphia Metals, LLC
  (952) 758-7500, New Jersey
  www.adelphiametals.com
- Harris Supply Solutions, Inc.
  (443) 683-9143, Maryland
  www.harrissupplysolutions.com

FOR THREADED BAR, SOIL NAILS & FASTENERS

- Williams Form Engineering, www.williamsform.com

FOR COUPLERS

- Barsplice Products, Inc.
  www.bars splice.com
- Dextra
  www.dextragroup.com
- Erico
  www.erico.com
- HRC
  www.hrc-usa.com
- Williams Form Engineering
  www.williamsform.com

For more technical information, please visit our website www.mmfx.com