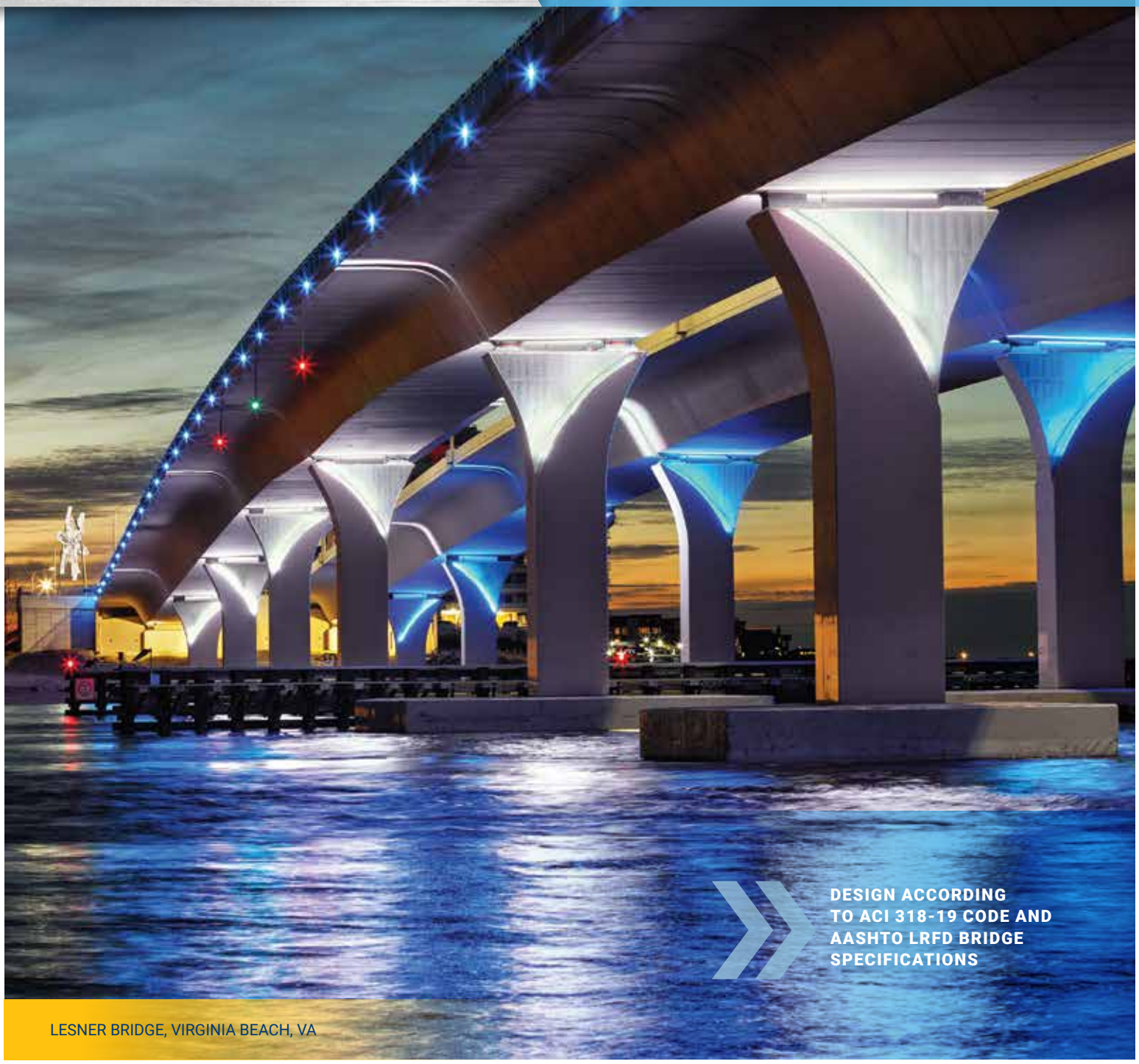
COMMERCIAL METALS COMPANY

CHROMX®

BRIDGE AND HIGHWAY REINFORCING SOLUTIONS



DESIGN ACCORDING TO ACI 318-19 CODE AND AASHTO LRFD BRIDGE SPECIFICATIONS

LESNER BRIDGE, VIRGINIA BEACH, VA

Because rust never sleeps

ChromX® concrete reinforced steel products remove the long-standing limitations faced by structural engineers and the construction industry by introducing varying levels of corrosion resistance. ChromX® steel, an MMFX innovation, 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 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. Now designers can utilize these high strength efficiencies and best match the corrosion protection requirements of any given project.

ChromX® 9000 Series

(ASTM A1035 CS, 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® 9000.

ChromX® 4000 Series

(ASTM A1035 CM, GRADE 100 OR 120)

This product 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® 2000 Series

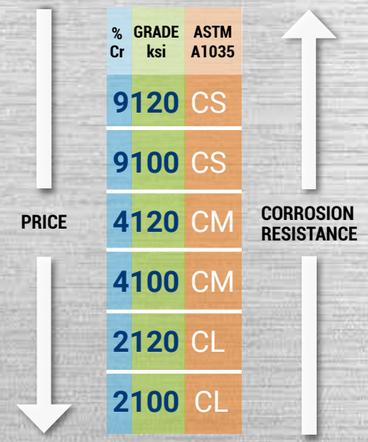
(ASTM A1035 CL, GRADE 100 OR 120)

The ChromX® 2000 Series is a lower 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.

*Minimum order quantity required

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.

STEEL GRADE CHART



ELIGIBLE FOR LEED CREDITS IN THE “MATERIALS AND RESOURCES” AND “INNOVATION IN DESIGN” CATEGORIES

The right product for the right need

ATMOSPHERIC ZONE
ChromX® 2100

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

DECK & DEICING SALT SPRAY ZONE
ChromX® 9100

or 9100.
ChromX® 9100 should be used in the areas of a bridge where deicing

SPLASH & TIDAL ZONES
ChromX® 9100

salts are used.
The splash zone is a severe corrosive environment requiring ChromX® 9100's corrosion

SUBMERGED ZONE
ChromX® 9100 or 4100

protection.
Designers should consider ChromX® 9100 or 4100 for the submerged zone, which is less corrosive than

EMBEDDED ZONE
Chromx® 2100

the splash 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.

Efficient bridge design techniques

Design, installation and condition assessment of a concrete bridge deck constructed with ASTM A1035 CS #4 Bars

BY VIRGINIA CENTER FOR TRANSPORTATION INNOVATION & RESEARCH

REFERENCE: Final Report VCTR 17-R16 / A. Salomon; C. Moen (June 2017)

- **Using higher yield stress from ChromX® 9100 to replace #5 bars with #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**

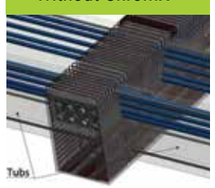
Structural design guidelines for concrete bridge decks using high strength and corrosion resistant reinforcing (CRR) Bars

BY VIRGINIA CENTER FOR TRANSPORTATION INNOVATION & RESEARCH

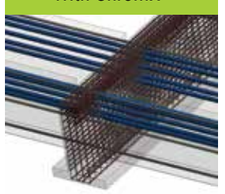
REFERENCE: Final Report VCTR 15-R10 (October 2014)

- **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**

Without ChromX®



With ChromX®



Alternative to post-tensioning for pier cap

BY ECONSTRUCT.USA, LLC

REFERENCE: MMFX Steel (now MMFX Technologies) Alternative to Post-Tensioning for Pier Cap, eConstruct.USA, LLC (2015)

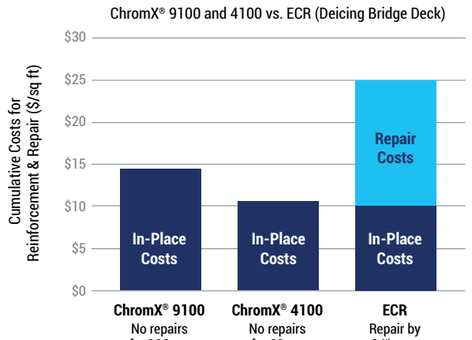
- **Simplifying construction steps**
- **Reducing pier cap weight**
- **Reducing concrete**
- **Saving on reinforcement and post-tensioning costs**

Value that's cast in concrete

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, the initial minor differences in construction costs for using ChromX® will be significantly less than the eventual repair costs incurred from not using ChromX®. Over time, ChromX® rebar can greatly reduce the overall cost of a structure.

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



EXTENDING LIFE LOWERS COSTS

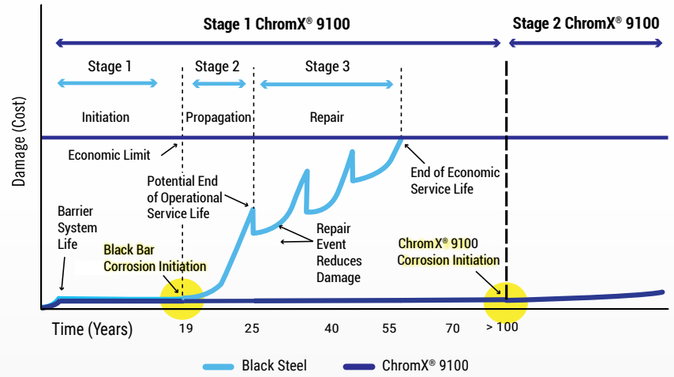
The service life (the time to the first repair) is driven by the corrosion of the reinforcing steel. Reinforcing steel corrosion begins when the chloride concentration at the steel surface reaches the critical chloride threshold (CT) value of that steel. The corrosion continues at the corrosion rate (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 can be damaged due to field handling and installation, and therefore provides limited protection.

ChromX® rebar's **CR value is 1/3** that of black bar

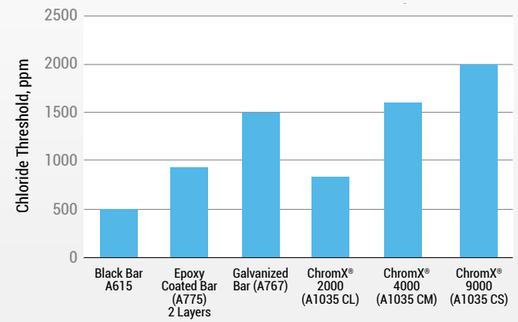
ChromX® 9100's **CT value is 4x** that of black bar and twice that of galvanized bar



Corrosion timeline, Black Bar vs. ChromX® 9100

Black bar reaches its end of economic life before corrosion initiation even begins for ChromX® 9100

Estimated chloride threshold used in modeling service life



Comparison of service life and life cycle cost analysis (LCCA) in bridge decks

REINFORCING BAR	Service Life[1]	Est. Initial Cost	50-yr. LCCA[2]	75-yr. LCCA[2]	100-yr. LCCA[2]
Black Bar	25	$7.32	$16.07	$18.77	$19.30
Epoxy Coated	34	$10.08	$16.23	$17.45	$18.50
Galvanized	55	$13.68	$13.68	$16.38	$16.91
ChromX® 2100[3]	40	$9.24	$12.36	$15.06	$15.60
ChromX® 4100	61	$9.72	$9.72	$11.09	$12.28
ChromX® 4100 w/CNI[4]	>100	$10.03	$10.03	$10.03	$10.03
ChromX® 9100	>100	$14.52	$14.52	$14.52	$14.52
Stainless Steel (UNS S32304)	>100	$25.32	$25.32	$25.32	$25.32

[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.

High strength bridge design specifications

High strength tensile properties

TYPE	A1035 CL		A1035 CM		A1035 CS	
GRADE	Grade 100 (690)	Grade 120 (830)	Grade 100 (690)	Grade 120 (830)	Grade 100 (690)	Grade 120 (830)
Tensile strength, min, psi (MPa)	150,000 (1030)	150,000 (1030)	150,000 (1030)	150,000 (1030)	150,000 (1030)	150,000 (1030)
Yield strength (0.2% offset), min, psi (MPa)	100,000 (690)	120,000 (830)	100,000 (690)	120,000 (830)	100,000 (690)	120,000 (830)
Elongation in 8 in. (200 mm), min, %: Bar Designation No.						
3 through 8 (10 through 25)	7	7	7	7	7	7
9 through 20 (29 through 64)	6	6	6	6	6	6

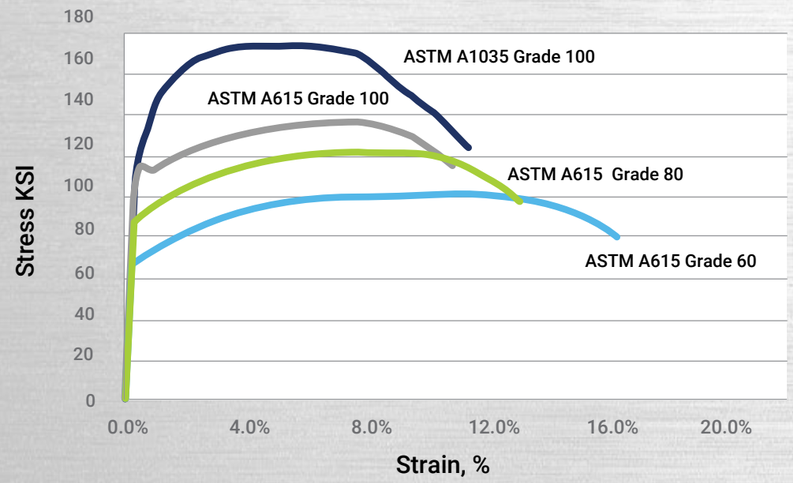
Maximum tensile strengths (ksi) of reinforcement for use in bridge designs[1]

SEISMIC ZONES	FOUNDATIONS			COLUMNS / WALLS		DECKS	BEAMS / GIRDERS	
	Abutments	Piles	Pile Caps	Vertical	Confinement	Top & Bottom	Tension	Compression
Zone 1	100	100	100	100	100	100	100	100[2]
Zone 2	100[3]	100[3]	100[3]	100[4]	100[3]	100	100	100[2]
Zone 3	100[3]	100[3]	100[3]	N/R[5]	100[3]	100	100	100[2]
Zone 4	100[3]	100[3]	100[3]	N/R[5]	100[3]	100	100	100[2]

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.

(1) Design Guide for Use of ASTM A1035 High-Strength Reinforcement in Concrete Bridge Elements with Consideration of Seismic Performance, H.G. Russell, S.K. Ghosh, Mehdi Saiidi (2011) and Design Guide for Use of ASTM A1035 High-Strength Reinforcement in Concrete Bridge Elements in AASHTO Seismic Zone 2, S.K. Ghosh (2012).
(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.

Stress / strain curves of ChromX® (ASTM A1035 CS, CM, CL) vs. ASTM A615

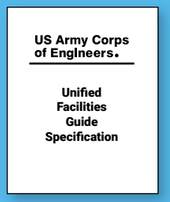


Specifications & design codes

ACI 439.6R-19 guide for the use of ASTM A1035/A1035M type CS Grade 100 (690) steel bars for structural concrete

ICC-ES ESR-2107 ASTM A1035/A1035M Grade 100 steel reinforcing bars

AASHTO LRFD bridge specifications bridge design for the use of ASTM A1035/A1035M Grade 100 (690 MPa) steel bars for bridge structures



USACE unified facilities guide specification

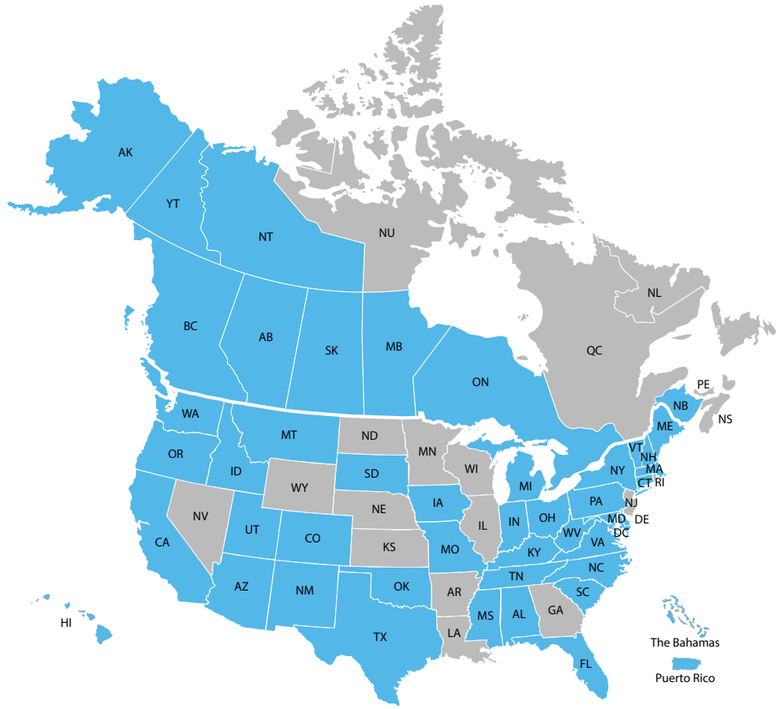
ACI 318-19 Building Code Requirements for Structural Concrete

For detailed specifications, visit cmc.com/chromx

Just about everywhere

ChromX® steel products have been used to build bridges and highways throughout North America.

States, provinces and territories where bridges have been constructed using A1035 (ChromX®).



Dowel bars

ChromX® uncoated corrosion resistant steel pavement dowel and tie bars extends 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 1¼" or 1½" 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.

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.

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How can we help you with your next project?

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CMC Commercial Metals

it's what's **inside** that counts

We're Commercial Metals Company — CMC, for short. You'll find our steel in sports stadiums and public buildings as well as highways, bridges, railways and other structures nearly everywhere on the planet.

To serve this global market, CMC maintains facilities across the United States, Europe and Asia. These sites include everything from local recycling centers, steel mini-mills and micro-mills to large-scale fabrication centers, heat-treating facilities and other metals-related operations.

RECYCLING | MILLS | FABRICATION **cmc.com/chromx**