COMMERCIAL METALS COMPANY

CHROMX®

MARINE STRUCTURE REINFORCING SOLUTIONS

DESIGN ACCORDING TO ACI 318-19 CODE

GULF STATE PARK FISHING PIER, GULF SHORES, AL

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

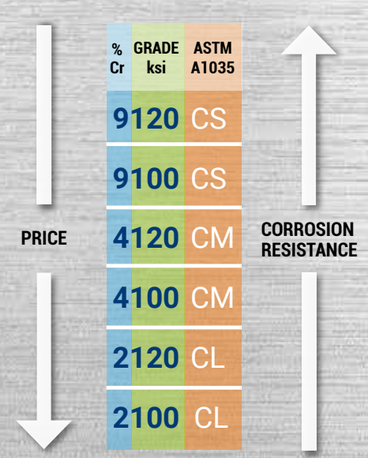
(ASTM A1035 CL, GRADE 100 OR 120)

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® 9100 or 4100

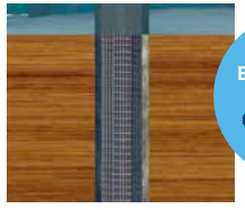
A marine atmosphere is very corrosive due to chloride exposure from salt spray, salt fog and salt mist. For atmospheric pier members in marine environments designers should consider using ChromX 4100 or 9100 depending on the target service life for the structure.

SPLASH & TIDAL ZONES
ChromX® 9100

The splash and tidal zones are generally severe corrosive environments due to repeated wet and dry saltwater exposures, requiring ChromX 9100's corrosion protection.

SUBMERGED ZONE
ChromX® 9100 or 4100

While actually less corrosive than the splash zone, designers should consider ChromX 9100 or 4100 for the submerged zone.



EMBEDDED ZONE
Chromx® 2100

There is usually lower corrosion potential in the embedded zone depending on the composition and contents of the soil, therefore ChromX 2100 may be a good choice.

Efficient marine structure design examples

United States Navy Modular Hybrid Precast Concrete Pier

BY NAVAL FACILITIES ENGINEERING COMMAND

- **100 year service life**
- **$2.8 million in savings by substituting ChromX 9100 for stainless steel rebar in select sections**

REFERENCE: New Technology Proven in Precast Concrete Modular Floating Pier for U.S. Navy, PCI Journal (October 2005)

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

BY VIRGINIA CENTER FOR TRANSPORTATION INNOVATION & RESEARCH

- **Reduced steel weight by 36%**
- **Thinned clear cover from 2.5 to 2.0 inches**
- **Identified significant savings in construction costs and time**
- **Improved serviceability**

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

Adjustable Permeable Groins
Cortez, FL

Seawall, North Beach Blvd.
Bay St. Louis, MS

Gulf State Park Fishing Pier
Gulf Shores, AL

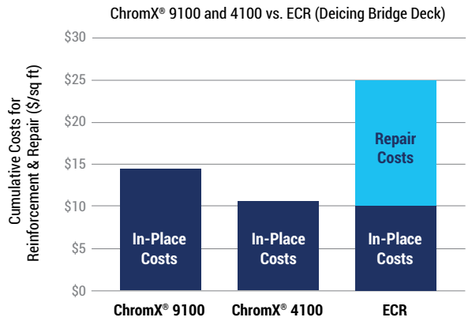
Diaphragm Wall
Al Maryah Island, Abu Dhabi, UAE

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

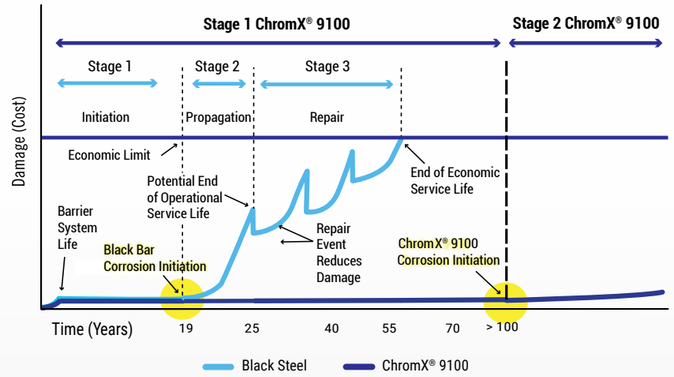
The service life (the time to the first repair) is driven by the corrosion of the reinforcing steel. Reinforcing steel corrosion begins when the chloride concentration at the steel surface reaches the critical chloride threshold (CT) value of that steel. The corrosion continues at the corrosion rate (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.

ChromX® rebar's **CR value is 1/3** that of ASTM A615

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

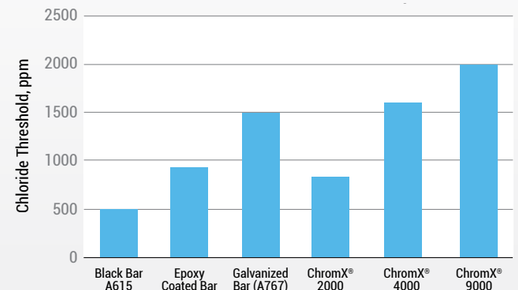
Additionally, perfectly applied epoxy coating performs well in laboratory tests, but field studies prove that the coating can be damaged due to field handling and installation, and therefore provides limited protection.



Corrosion timeline, ASTM A615 vs. ChromX® 9100

ASTM A615 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 initial cost analysis in low permeability marine piles

REINFORCING BAR	Est. Initial Cost*	Service Life Years (2.0" cover)**	Service Life Years (2.5" cover)
ASTM A615	$0.61	26	37
Epoxy Coated	$0.84	35	46
Galvanized	$1.14	64	89
ChromX® 4100	$0.81	56	76
ChromX® 4100 w/CNI[4]	$0.86	94	>100
ChromX® 9100	$1.21	>100	>100
Stainless Steel (UNS S32304)	$2.11	>100	>100

* Estimate initial cost per pound installed including materials, fabrication and placement estimated costs as of date of publication. Adding 2 gallons of calcium nitrite (CNI) as a concrete additive at an estimated cost of $12.00 per cubic yard of concrete has been shown to further enhance ChromX 4100's corrosion performance. With a ratio of rebar to concrete for a typical marine pile ranging from 160 to 240 lbs. of rebar per cubic yard, the additional CNI cost would range from $0.05 to $0.075 per lb of rebar.

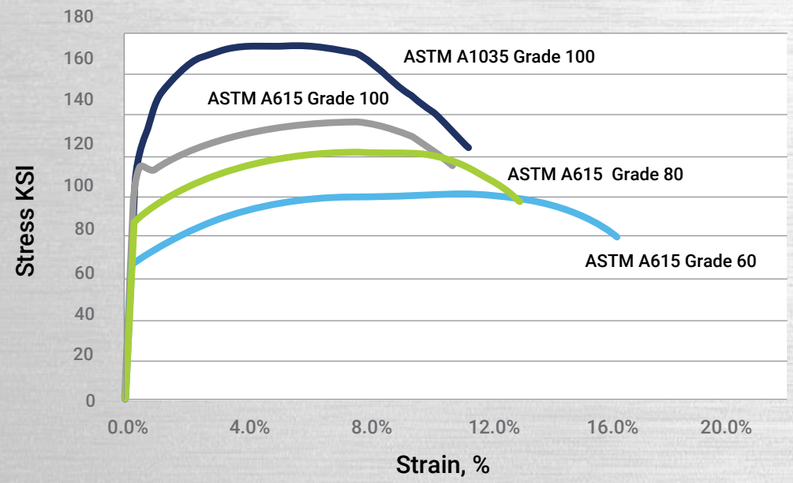
** Service lives estimated based on CT values determined in Critical Chloride Corrosion Threshold for Galvanized Reinforcing Bars, David Darwin, et al, Univ. of Kansas Center for Research, Inc. (Dec. 2007), as well as CT and CR values and Stadium Modeling for marine piles using 2.0 and 2.5 inches of Pile Mix LP concrete cover according to Reinforcing Steel Comparative Durability Case Studies and 100 Year Service Life Cost Analysis Report, Tourney Consulting Group, LLC (2016).

High strength marine design specifications

High strength tensile properties

CHROMX	2100	4100	9100
SPECIFICATION GRADE	ASTM A1035 CL 100 (690)	ASTM A1035 CM 100 (690)	ASTM A1035 CS 100 (690)
Tensile strength, min, psi (MPa)	150,000 (1030)	150,000 (1030)	150,000 (1030)
Yield strength (0.2% offset), min, psi (MPa)	100,000 (690)	100,000 (690)	100,000 (690)
Elongation in 8 in. (200 mm), min, %: Bar Designation No.			
3 through 11 (10 through 36)	7	7	7
14, 18 (43, 57)	6	6	6

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



Value engineering with ChromX

Seawall design comparison table - Dubai diaphragm wall example

METRICS	GRADE 460 ECR	GRADE 600 CHROMX 9100	ADDED COST/SAVINGS	%
Rebar quantities (metric tons)	20,000	15,333	(4,667)	-23%
Steel related costs	$37,100,000	$39,943,333	$2,843,333	8%
Concrete costs	$37,970,323	$34,173,290	($3,797,032)	-10%
Other expenses: excavation	$3,043,591	$2,739,232	($304,359)	-10%
Total construction costs	**$78,113,914**	**$76,855,856**	**($1,258,058)**	**-2%**
Number of trucks	22,448	20,107	(2,342)	
Construction time (in hours)	2,924	2,338	(586)	
Construction time savings				**-20%**
Service life	34	101	67	
NPV of repairs	$25,911,409	$0	$25,911,409)	
Total life cycle costs	$104,025,323	$76,855,856	($27,169,467)	
Life cycle cost analysis savings				**-26%**

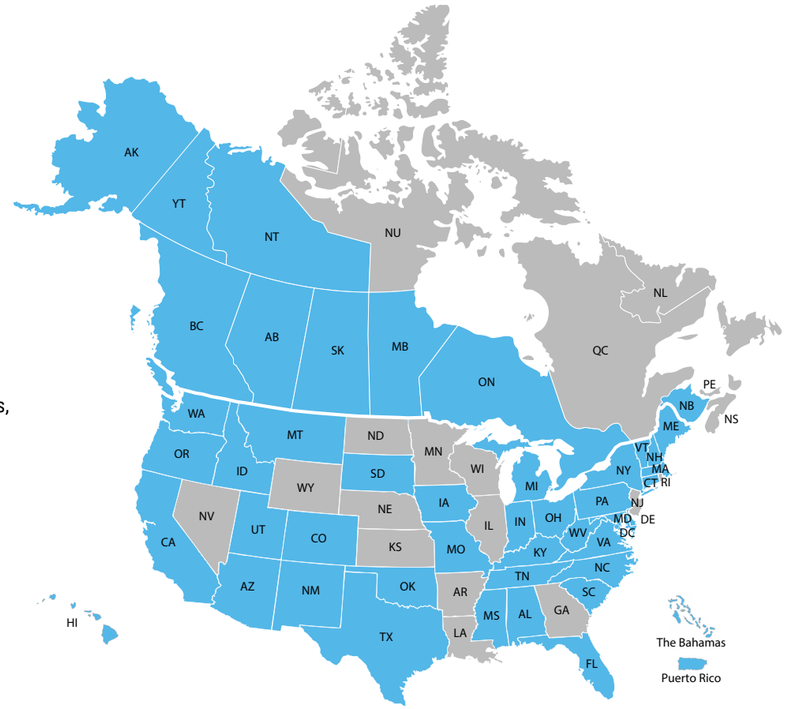
To illustrate the value engineering potential of ChromX 9100 rebar, the table above provides a comparison of ChromX 9100 rebar to epoxy-coated rebar (ECR) using the Dubai, UAE, diaphragm wall as an example, which was redesigned to Grade 600 versus Grade 460. The design engineers elected to only design up to 600 MPa for this seawall application. U.S. cost factors of materials and labor were used for this comparison.

By designing a seawall at 600 MPa compared to 460 MPa, the designers were able to:

- Reduce the wall thickness by 10%, saving valuable real estate along the length of the wall.
- Save approximately 2% of upfront construction costs, assuming using ChromX 9100 over epoxy-coated rebar.
- Reduce construction time by 20%.
- Lower life cycle costs with the superior corrosion protection of ChromX 9100.

Just about everywhere

ChromX® steel products have been used to build seawalls, bridges, piers, roadways and more throughout North America.



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

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

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

ACI 318-19
Building Code Requirements for Structural Concrete

For detailed 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.

803.254.4660,
Eastern U.S.

512.282.8820,
Central U.S.

909.803.1500,
Western U.S. & Hawaii

How can we help you with your next project?

866.466.7878
chromX@cmc.com

WE'RE HERE TO SUPPORT YOU

Learn more about ChromX®

866.466.7878 | chromX@cmc.com

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**