



*Now Design
According to
ACI 318-19 Code*

CHROM^X

**MARINE STRUCTURE
REINFORCING
STEEL SOLUTIONS**

CORROSION RESISTANT • EXTENDED LIFE CYCLE • REDUCED COSTS

MMFX TECHNOLOGIES, A COMMERCIAL METALS COMPANY | WWW.CMC.COM/CHROMX

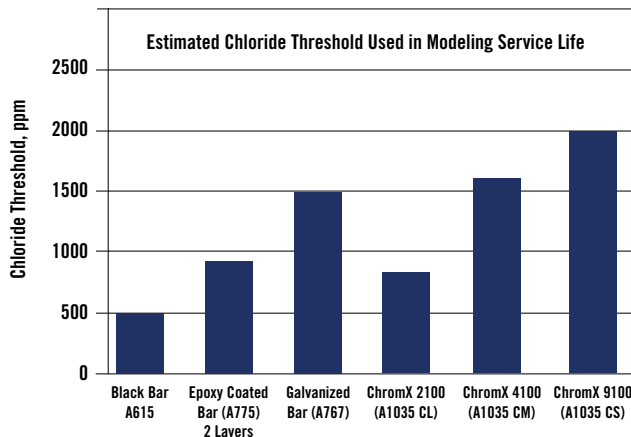
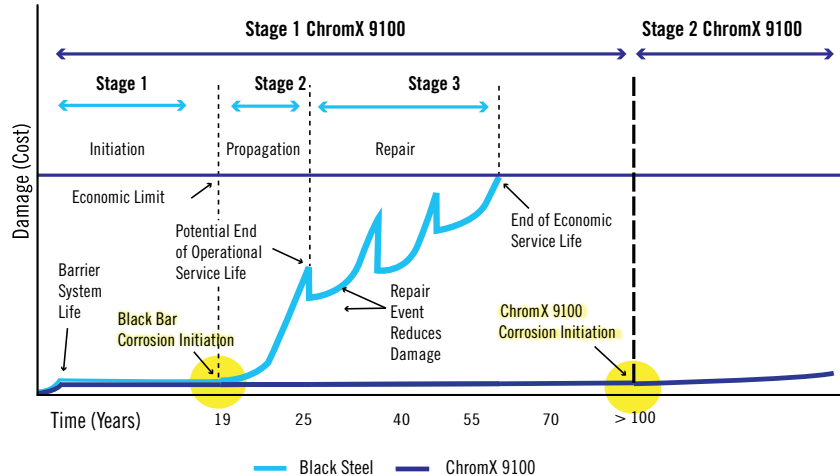
Service Life and Lower Life Cycle Costs

ChromX Concrete Reinforcing Steels

ChromX concrete reinforcing steel 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.

Corrosion Timeline, Black Bar vs. ChromX 9100
Black bar reaches its end of economic life before corrosion initiation even begins for ChromX 9100



The CT of ChromX 9100 is four times that of Black Bar and twice that of ChromX 4100. In addition, both ChromX 9100 and 4100 have a CR value of one-third that of Black Bar. These higher CT and lower CR values are the reason 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.

Chart Notes:

¹ Darwin, David et al, Critical Chloride Corrosion Threshold for Galvanized Reinforcing Bar, The University of Kansas Center for Research, Inc. (Dec 2007).

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.

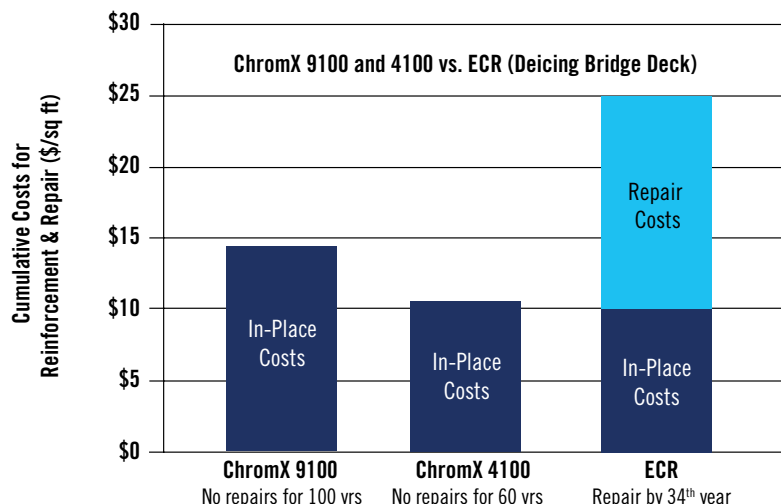
³ ChromX 4100 comparison figure based on Tourney Consulting Group, LLC, Reinforcing Steel Comparative Durability Case Studies and 100 Year Service Life Cost Analysis Report, Tourney Consulting Group, LLC (2016).

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.

Savings Realized Upon First Repair of ECR

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



Service Life Designs

The Full ChromX Product Line

Areas of the same marine structure have different corrosion protection requirements. The full ChromX product line (9100, 4100 and 2100) allows designers to mix and match, and select the product that best fits the application. A pier is shown as an example below.



- » **Atmospheric Zone** 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 and Tidal Zones** 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** While actually less corrosive than the splash zone, designers should consider ChromX 9100 or 4100 for the submerged zone.
- » **Embedded Zone** 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.

Case Study Corrosion Service Life for Various Reinforcing Steels in Low Permeability Marine Piles

Reinforcing Bar	Est. Initial Cost (\$/lb)*	Service Life Years (2.0" cover)**	Service Life Years (2.5" cover)
Black Bar	\$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	\$0.86	94	>100
ChromX 9100	\$1.21	>100	>100
Stainless (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, Tournay Consulting Group, LLC (2016).

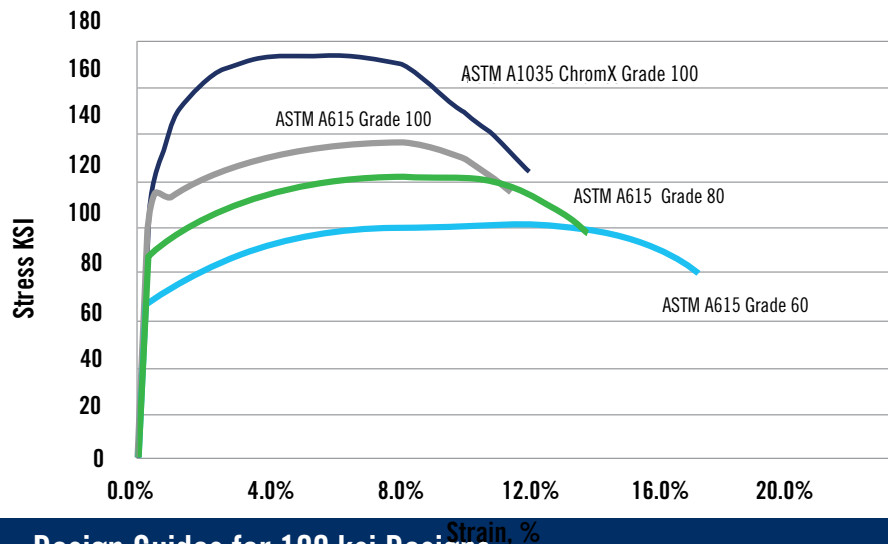
High Strength Designs

ChromX Concrete Reinforcing Steels

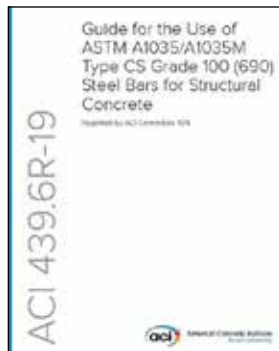
High Strength Tensile Properties per ASTM A1035

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] 14, 18 [43,57]	7 6	7 6	7 6

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



Design Guides for 100 ksi Designs



ACI 439.6R-19
Guide for the Use of ASTM
A1035/A1035M Type CS Grade
100 (690) Steel Bars for
Structural Concrete



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



ICC-ES ESR-2107
Grade 100 Steel
Reinforcing Bars



ACI 318-19
Building Code Requirements
for Structural Concrete

Value Engineering with ChromX Reinforcing Steel

Comparison Using High Strength, Corrosion Resistant Rebar

To illustrate the value engineering potential of ChromX 9100 rebar with both its corrosion resistance and high strength properties, the table below provides a comparison of ChromX 9100 rebar to epoxy-coated rebar (ECR) using a specific redesigned seawall as an example. This Dubai, UAE, diaphragm wall was redesigned to Grade 600 versus Grade 460 design. 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.

ChromX 9100 rebar was estimated to provide an upfront construction cost savings of 2% and a 20% reduction in construction time. Further, the high strength redesign reduced the thickness of the wall by 10%, saving valuable real estate along the canal.

In addition, ChromX 9100 rebar provides over 100 years of service life in concrete compared to only 34 years estimated for ECR. ChromX 9100's corrosion resistance is estimated to reduce the life cycle costs over a 100-year service life by 26% for a total savings of over \$27 million.

Again, the savings in repair costs are realized upon the initial repair of the ECR structure, which is estimated to be within 34 years of construction. These initial repair costs alone are estimated at a net present value of \$9.7 million. Combined with the estimated upfront construction cost savings from the high strength design, the total savings realized from using ChromX 9100 rebar is approximately \$11 million within the first 34 years, with many more subsequent repairs scheduled for the ECR structure.



Efficient Dubai Diaphragm Wall (Seawall) Design Summary

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.

High Strength Steel & Corrosion Resistant Rebar Seawall Design Comparison Table

Seawall Example - Metric	Grade 460 ECR	Grade 600 ChromX 9100	Added Cost / Savings	%
8/27/2015				
Construction Costs				
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 Construction Expenses:				
Excavation	\$3,043,591	\$2,739,232	(\$304,359)	-10%
Total Construction Costs	\$78,113,914	\$76,855,856	(\$1,258,058)	-2%
Other VE Considerations				
Number of Trucks	22,448	20,107	(2,342)	
Construction Time (in hours)	2,924	2,338	(586)	
Construction Time Savings				-20%
Service Life & LCCA				
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%

Applications

ChromX Has Been Used In:

- » Seawalls
- » Piers
- » Canals and waterways
- » Ports
- » Marinas
- » Permeable groins and jetties



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

Other Examples of Efficient Design Techniques Using ChromX



United States Navy Modular Hybrid Precast Concrete Pier by Naval Facilities Engineering Command

ChromX 9100 was used along with other innovations in a floating modular pier resulting in:

- » 100-year service life
- » \$2.8 million 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

- » 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)



Qualified Fabricators

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 Technologies delivers solutions to problems faced by steel consumers. As a dependable technical resource, MMFX Technologies continuously strives to deliver unmatched value to its customers through the application of advanced nano steel technology.

MMFX Technologies has removed long-standing limitations faced by structural engineers and the construction industry by introducing its ChromX brand of 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

866.466.7878

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