Design and Specifying A1035 Corrosion Resistant and High Strength Reinforcing Steel

Bethany Hennings Cascade Steel Rolling Mills

History of Reinforcing Steel

Increasing Strength



First reinforced concrete structures in 1884

First uses of corrosion mitigation

- 1930s Galvanized
- Late 1930s Stainless Steel
- 1973 Epoxy Coating
- 2000 A1035 (MMFX)

What is ASTM A1035

- Deformed and Plain, Low-Carbon, Chromium Steel Bars for Concrete Reinforcement
- Known in the industry as MMFX, MMFX2, ChromX



Martensitic

M Microcomposite









ASTM Designation: A1035/A1035M-16 Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Reinforcement

- First ASTM A1035 Standard issued in 2004
- 2015 Standard Modified to include the ChromX Series
- Grade 100 (690 MPa) and Grade 120 (830 MPa) rebar



Guidelines, Codes and Specifications for Designing to 100 ksi (690 MPa) ASTM A1035

ACI ITG-6R (2010)

Design Guide for the Use of ASTM A1035/A1035M Grade 100 (690) Steel Bars for Structural Concrete





Guidelines, Codes and Specifications for Designing to 100 ksi (690 MPa)

AASHTO LRFD Bridge Design Specifications (Edition 7, 2014) Bridge Design Code for the Use of ASTM A1035/A1035M Grade 100 (690 MPa) Steel Bars for Bridge Structures







AASHTO Designation: MP 18M/MP 18-09

Uncoated, Corrosion-Resistant, Deformed and Plain Alloy, Billet-Steel Bars for Concrete Reinforcement and Dowels

- Reference ASTM A1035
 Standard
- ChrōmX 9100



What makes ChrōmX steel different from other rebar? ChrōmX micro-structure prevents conventional steel corrosion mechanisms

Typical Steel Microstructure



- Mild steel's microstructure is a mix of ferrite and iron carbide
- Together in the presence of moisture, chlorides & oxygen, the ferrite and iron carbide form galvanic cells (like batteries), which accelerate the process of corrosion from the inside out



- Carbide Typical
- Grain boundary with carbides

ChrōmX Microstructure



ChrōmX lamellar structure of martensite and retained austenite achieves high strength with ductility

Normal Steel Reinforcing

Chemical Composition of ASTM A1035 Alloy Types

Composition Max, % ^A								
ChrōmX Series	Alloy Type	Carbon	Chromium	Manganese	Nitrogen	Phosphorus	Sulfur	Silicon
2000	1035 CL	0.3	2.0-3.9	1.5	0.05	0.035	0.045	0.5
4000	1035 CM	0.2	4.0-7.9	1.5	0.05	0.035	0.045	0.5
9000*	1035 CS	0.15	8.0-10.9	1.5	0.05	0.035	0.045	0.5
		\bigcirc	\bigcirc					

*Formerly sold as MMFX₂

MMFX Reinforcing

Typical cooling rate (now forms martensite)

Quench in water (still forms martensite)

High Strength

Congested Beam to Col. Joint

CONCRETE CONSTRUCTION

Columns and Structural Walls

Reinforcement Transition

Too dense...

Designing With 100 ksi (690 MPa) ChrōmX in Confinement

60 ksi (420 MPa) confinement ties #5 @ 2 ¼" vertical spacing

Full-Size Replica of two columns

100 ksi (690 MPa) confinement ties #5 @ 4" vertical spacing

ChromX high strength for Less Rebar Congestion

Use of A1035

- FHWA
- Provinces
 - » British Columbia
 - » Alberta
 - » Saskatchewan
 - » Manitoba
 - » Ontario

States

- » Virginia
- » Florida
- » California
- » Oregon

- » Washington
- » Idaho
- » Oklahoma
- » New York
- » Hawaii
- » Utah
- » Montana
- » Louisiana
- » New Jersey
- » South Dakota

Corrosion Applications

United States Navy Modular Hybrid Precast Concrete Pier in San Diego, CA

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US Navy – Naval Facilities Engineering Command Modular Hybrid Pier (MHP), Tacoma to San Diego

- Precast Concrete Modular Floating Pier
- Constructed in Tacoma, WA
 Towed 1,200 miles to San Diego, CA
- Corrosion Resistant Reinforcing
- **75 to 100 years repair-free service life**

Corrosion and High Strength (Grade 100) Applications Daggett Road Bridge in Stockton, CA

Daggett Road Bridge over Burns Cut-off – 100 ksi design Constructed 2006

Corrosion and High Strength Applications Oklahoma DOT

State Hwy 100 over Illinois River - Lake Tenkiller Spillway Constructed 2006

ChrōmX 9100 in Abutments, Columns and Deck

Corrosion Applications Huguenot Bridge Replacement in Richmond, VA

Huguenot Bridge Replacement over James River Constructed 2013

ChrōmX 9100 in Deck

Corrosion Applications - Dowels US 395 North Spokane, WA

North Spokane Corridor – 1.5 in. dia. by 18 in. pavement dowel bars Constructed 2011

Specifying ASTM A1035

Make sure to use ASTM designations A1035/CS » ChromX9100 A1035/CM » ChromX4100 A1035/CL » ChromX2100

Information for specification, fabrication, estimating, detailing and placement of reinforcing steel bars specified for improved corrosion resistance, or other special uses or conditions.

Specifying

Bar supports

- » Same as for black bar
- No welded splices allowed
- Same bend diameters as black bar
- Shear cut or fluid-cooled saw
 - » Torch cutting should not be allowed
- Approved end anchors and mechanical connectors

Mechanical Splices & Anchorages (Headed Bars)

Specifying Handling and Storage

- Handled the same as for black bar
- If stored outside more than two months

» Polyethylene sheeting or other» Store on dunnage

Specifying For the Field

- No welding allowed
- Mill scale may show surface rust
- Field bending
 - » Same rules as for black bar
- Field cutting
 - » Same rules as for black bar
- Tying
 - » Same rules as for black bar

Schedule

ChromX 9100 » Rolls each cycle » Carry inventory of most bar sizes ChromX 4100 and 2100 » Rolled to order » Small inventory

Pricing has been more stable than black bar Price depends on level of corrosion resistance Maximum corrosion resistance roughly 3x black bar » Less than stainless

Not Just Research

Almost Ten Years Later

Outside Exposure

Great Performance

Thank you, Any Questions?

