Technical Note

Frequently Asked Questions (FAQ) About Low-Carbon, Chromium ASTM A1035 Types CS, CM and CL Steel Reinforcing Bar

Introduction

The Concrete Reinforcing Steel Institute (CRSI) routinely receives inquiries concerning various aspects of steel reinforcing bars, and reinforced concrete design and construction. This Technical Note presents a collection of typical questions that are asked regarding low-carbon, chromium steel, which is known as ASTM A1035 Types CS, CM and CL reinforcing bars. Most of these questions come from licensed design professionals (LDPs): structural engineers, architects, field personnel (inspectors, code enforcement personnel, and contractors), FHWA, USDOT, and US state and Canadian transportation agencies.

ASTM A1035 steel reinforcing bars provide a combination of high tensile strength to yield ratio and ductility. These material properties are a consequence of ASTM A1035’s chemistry and controlled rolling manufacturing process that result in a fine-grained lath martensite/austenite microstructure. Offering varying levels of corrosion-resistance, ASTM A1035 Type CS, CM, and CL bars are used in a wide range of reinforced concrete structures in different exposure conditions such as in high-rise towers, bridges, coastal marine structures and innovative design solutions using high strength efficiencies.

Specific frequently asked questions (FAQ) and responses follow.

Basic Material Characteristics

What Standards govern Low-Carbon, Chromium steel reinforcing bars?

Low-carbon, chromium steel reinforcing bars should be specified according to ASTM A1035/A1035M, Standard Specification for Deformed and Plain Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement, which references three alloy Types: CS, CM and CL with two yield strengths (100 ksi and 120 ksi).

What is the chemical composition of ASTM A1035 steel reinforcing bars? What alloy levels are required under the ASTM A1035 standard?

ASTM A1035 is a low-carbon, chromium alloy steel reinforcing bar. The chemical composition of ASTM A1035 steel reinforcing bars is shown in Table 1. ASTM A1035 steel reinforcing bars’ chemical composition should be selected for suitability to the corrosion application.

Are ASTM A1035 type bars patented and/or proprietary?

ASTM A1035 is an industry standard that is not patented. As per ASTM A1035 published notes, MMFX Technologies Corporation has several patented materials (US Patents #6,273,968, #6,709,534, #7,118,637, #7,186,363, #7,277,687).

Table 1 - ASTM A1035 Chemical Compositions of Alloy Type
(Maximum weight percentage of chemical constituents, except where noted (1))

<table>
<thead>
<tr>
<th>Alloy Type</th>
<th>C%</th>
<th>Cr%</th>
<th>Mn%</th>
<th>Si%</th>
<th>S%</th>
<th>P%</th>
<th>N%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A1035 Type CS</td>
<td>0.15</td>
<td>8.0 to 10.9(1)</td>
<td>1.5</td>
<td>0.5</td>
<td>0.045</td>
<td>0.035</td>
<td>0.05</td>
</tr>
<tr>
<td>ASTM A1035 Type CM</td>
<td>0.2</td>
<td>4.0 to 7.9(1)</td>
<td>1.5</td>
<td>0.5</td>
<td>0.045</td>
<td>0.035</td>
<td>0.05</td>
</tr>
<tr>
<td>ASTM A1035 Type CL</td>
<td>0.3</td>
<td>2.0 to 3.9(1)</td>
<td>1.5</td>
<td>0.5</td>
<td>0.045</td>
<td>0.035</td>
<td>0.05</td>
</tr>
</tbody>
</table>

(1) Range is given as per ASTM A1035
Frequently Asked Questions (FAQ) about Low-Carbon, Chromium ASTM A1035 Types CS, CM, and CL Steel Reinforcing Bar [ETN M-11-17]

What are the available types, sizes and lengths of ASTM A1035 steel reinforcing bars?

Bars meeting ASTM A1035 Types CS, CM, and CL steel reinforcing bars are available in the U.S. conventional bar sizes and the metric sizes used in Canada. U.S. bar sizes are #3 through #11, #14, and #18 (#10 through #36, #43, and #57). Metric sizes in Canada are 10M, 15M, 20M, 25M, 30M, 35M, 45M, and 55M. Smooth rounds are available 3/4" (19 mm) through 2-1/2" (64 mm). ASTM A1035 steel reinforcing bars are sold in standard bar lengths for US with #3 (#10) and #4 (#13) bars also available as coil. Custom mill-cut lengths are available by special order up to 72 feet (80 feet maximum for #11, #14 and #18) of 50 tons or greater increments. Threaded ASTM A1035 bars can also be provided.

What are the yield and tensile strengths of ASTM A1035 steel reinforcing bars?

ASTM A1035 Type CS, CM, and CL steel reinforcing bars are available in Grade 100 (690 MPa) with a minimum yield (f_y) of 100 ksi (690 MPa) and Grade 120 (830 MPa) with a minimum yield (f_y) of 120 ksi (830 MPa). Type CS, CM and CL 100 and 120 Grades have minimum ultimate tensile (f_u) strengths of 150 ksi (1030 MPa). All ASTM A1035 types have a minimum tensile to yield ratio of 1.25.

How are ASTM A1035 steel reinforcing bars marked? Are the deformations the same as the carbon steel reinforcing bar designations?

Markings on ASTM A1035 Grade 100 and 120 steel reinforcing bars indicate the point of origin, size designation (Arabic number corresponding to bar designation number), type of alloy (the letters “CS”, “CM” and “CL”) and grade 100 or 120. Figures 1 and 2 illustrate the markings on ASTM A1035 Types CS, CM and CL Grade 100 (690) steel reinforcing bars respectively.

ASTM A1035 steel reinforcing bars have the same deformation pattern as conventional steel bars.

Engineering Design Issues

What does a typical stress-strain curve look like?

ASTM A1035 steel reinforcing bars exhibit a “round-house” curve, as seen in high strength steels, when stress versus strain is plotted. This means the yield point of the stress-strain curve is less well-defined than with stress-strain curves for conventional steels, where
a well-defined yield plateau is exhibited. Figure 3 illustrates representative stress-strain curves for ASTM A1035 Type CS, CM and CL steel reinforcing bars produced according to ASTM A1035 Grade 100.

**Are there high strength design guidelines for ASTM A1035 steel reinforcing bars for use at 100 ksi and 120-ksi-design yield strength?**

ICC ES Evaluation Report ESR 2107 provides design guidelines on the use of ASTM A1035 steel reinforcing bars up to 100 ksi yield in structural designs in accordance to the Acceptance Criteria ICC AC429 that conform to the requirements of International Building Codes 2009, 2012 and 2015. ACI ITG-6 also provides design guidelines on the use of ASTM A1035 steel reinforcing bars up to 100 ksi yield in structural designs.

ESR 2107 also provides the following design guidelines:

- The reinforcing bars must not be used as longitudinal reinforcement in special moment frame members, special structural wall boundary elements or coupling beams,
- ASTM A1035 Grade 100 reinforcing bars must not be welded
- ASTM A1035 Grade 100 reinforcing bars must not be used as headed deformed bars in tension
- The specified compressive strength for concrete must range from 4,000 to 12,000 psi

AASHTO LRFD Bridge Design Specifications, allows the use of reinforcing steel up to 100-ksi yield strength in design, as per ASTM A1035 CS, CM and CL. Bridge seismic design guidelines have also been made.

The use of ASTM A1035 steel reinforcing bars in Seismic Zones 2, 3 and 4 and SDC D, E and F is limited to transverse reinforcement for concrete confinement with $f_{y}$ up to 100 ksi for special moment frames and special structural walls as permitted by Section 20.2.2.4 of ACI 318 and foundation mats where seismic movements aren’t an issue.

**Are ASTM A1035 steel mechanical couplers available? Can conventional carbon steel couplers be used with ASTM A1035 steel reinforcing bars?**

Mechanical couplers made from ASTM A1035 steel material or equivalent high strength material to conform to ASTM A1035 are commercially available. Other types of reinforcing bar accessories (e.g., transition sizes, end anchors, etc.) are available with adequate lead time and quantity. Manufacturers should be contacted for special orders. Conventional carbon steel couplers can be directly connected to ASTM A1035 steel reinforcing bars as there are no dissimilar metal issues between the two materials (“Galvanic Compatibility of 9 Cr-MMFX with A615 Steel Bars,” “Risk of Macro-Cell Corrosion Associated with Black Bar”). Coupler manufacturers’ high strength test data should be utilized to determine suitability of available products.

**Can ASTM A1035 steel reinforcing bars be connected to other steel reinforcing bars?**

Based on dissimilar metal testing of ASTM A1035 steel reinforcing bars in concrete with conventional carbon steel bars, ASTM A1035 bars can be directly connected to conventional carbon steel bars. Studies indicate no detrimental effects of connecting ASTM A1035 to conventional carbon steel reinforcing bars and other types of steel reinforcement (“Galvanic Compatibility of 9 Cr-MMFX with A615 Steel Bars,” “Risk of Macro-Cell Corrosion Associated with Black Bar”). ASTM A1035 bars can be used in areas of the structure requiring high-strength and/or corrosion-resistance, while conventional carbon steel can be used in areas of the same structure, in which high-strength and/or corrosion-resistance are not required.

**Do all ASTM A1035 steels have the same resistance to corrosion?**

No, not all ASTM A1035 alloys have similar corrosion properties. The steel bars produced to the requirements of ASTM A1035 provide varying levels of corrosion resistance. The severity of the service environment, expected chloride exposure, and service life should be considered when specifying the appropriate ASTM A1035 Type CS, CM or CL to use. Critical chloride threshold modeling, utilizing a distribution of possible threshold values, has been used to determine effective corrosion control strategies for reinforcing steel in concrete. Purchasers are encouraged to specify an alloy for applications in which specific properties are desired. Further, these desired properties should be identified prior to specifying which ASTM A1035 bar is appropriate for the application in question.

**What are the benefits of high strength design?**

Designing with high strength steels, such as ASTM A1035 Types CS, CM and CL steel reinforcing bars, may improve constructability and resolve congestion issues. ASTM A1035 and AASHTO MP 18’s high strength material properties also may provide efficiency in construction with the direct reduction in steel and concrete, as well
as the related labor costs, such as by reducing foundation thicknesses. Reducing foundation thicknesses may also shorten the construction schedule, which leads to earlier occupancy, income from commercial projects and use of public projects (i.e. highways etc.).

Fabrication and Construction Issues

Into what fabricated shapes can ASTM A1035 steel reinforcing bars be bent? Are there any special equipment and procedures used to fabricate ASTM A1035 steel reinforcing bars?

ASTM A1035 steel reinforcing bars can be fabricated into all standard bend shapes found in CRSI Manual Standard Practice and ACI ITG-6 Section 10.4. The bars are bent to the same diameters as conventional carbon steel reinforcing bars. Fabrication of ASTM A1035 steel reinforcing bars is accomplished using the same shearing and bending equipment and procedures that are used to fabricate conventional carbon steel reinforcing bars. As ASTM A1035 bars have a greater yield and tensile strength than conventional Grade 60 carbon steel reinforcing bars, they require more force to shear and bend. Saw cutting of ASTM A1035 steel reinforcing bars either at fabrication facilities or in the field should be accomplished using fluid-cooled saws. Torch cutting is prohibited.

What is the lead time necessary to order ASTM A1035 bars?

Inventories of ASTM A1035 Type CS steel bars and smooth rounds are maintained at the production mill and distributors throughout North America. Purchasers are encouraged to inquire with a local fabricator about lead times for specific grades, sizes, and quantities early in the project schedule. ASTM A1035 Types CM and CL bars are rolled to order in custom mill-cut bar lengths up to 72 feet and purchasers should allow additional lead time.

Can ASTM A1035 bars be welded in accordance with AWS welding procedures?

No AWS welding procedure for ASTM A1035 exists at this time, since welding temperatures lie outside of the controlled rolling temperatures that the bars are produced. As a result, the bars will not have the same microstructure, in the weld’s heat affected zone (HAZ), when they were originally produced. The change of microstructure in the weld’s HAZ, can result in different mechanical and corrosion properties than the remainder of the bar.

Is there any special handling, storage, or placing requirements for ASTM A1035 steel reinforcing bars?

ASTM A1035 steel reinforcing bars should be handled the same as conventional carbon steel bars in accordance with the CRSI Manual Standard Practice. During transportation and outside storage, ASTM A1035 steel reinforcing bars should be covered when exposed to the environment for 60 days or longer. Similar to conventional carbon steel bars, ASTM A1035 steel reinforcing bars should be stored off the ground using dunnage and kept free from mud, water, oils or other contaminants. Bar supports and other accessories used with ASTM A1035 bars can be the same as those used for conventional carbon steel bars. Heating of ASTM A1035 steel reinforcing bars during bending is not required and should not occur. The bars should also not be re-bent. The handling and placement of ASTM A1035 bars is similar to that of black bar. Further information is also available in the CRSI Specialty and Corrosion-Resistance Steel Reinforcement-Product Guide.

What is the cost of ASTM A1035 reinforcing bar compared with normal “black” bar or other corrosion resistant bars on the market?

As a trade organization, CRSI does not comment on cost. Costs will vary by location. Manufacturers or suppliers should be contacted for current pricing information.

Finish Quality

Is mill scale oxidation on the surface of the bars acceptable? What effect does it have on steel reinforcing bars service life?

Similar to ASTM A615, both ASTM A1035 and AASHTO MP 18 specifications contain statements concerning mill scale oxidation: “Seams, surface irregularities, or mill scale oxidation shall not be cause for rejection, provided the weight, dimensions, cross-sectional area, and tensile properties are not less than the requirements of this specification.” In addition, ACI 318 states that “...steel reinforcement with rust, mill scale, or a combination of both shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen comply with applicable ASTM specifications...”. Superficial surface oxidation generally does not affect the performance of ASTM A1035 steel reinforcing bars, although mill scale removal has been found to have a slight increase in corrosion resistance (“Comparative Corrosion Testing and Analysis of MMFX 2 Rebars for Reinforced Concrete Applications”). Similar to conventional carbon reinforcing steels and in accordance with the CRSI CTN-M-2 “Field Guide for Rust on Reinforcing Bars,” extensive loose or flakey mill scale should be cleaned from the bars during installation. See also CRSI ETN-M-5 “Rust, Mill Scale, and Outer Surface Constrants on Steel Reinforcing Bars.”

Mill scale oxidation can be minimized with proper transportation and field storage practices, as described in the answer to the above question concerning special handling, storage and placing requirements.
Contributors: The principal authors on this publication are David Miller PE and Dr. Salem Faza with review by members of the CRSI Durability Committee.

Keywords: Low-carbon chromium steel, reinforcing bar, deformations, couplers, corrosion, handling, storage.


Historical: None. New Technical Note.

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