# Reinforcing Steel Options for Concrete Construction

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CRSI Concrete Reinforcing Steel Institute

Concrete Reinforcing
Steel Institute

# About the Speaker
# Paul Dye

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- CRSI Pacific Northwest Region Manager – WA, OR, ID, AK, HI, UT, MT, WY, Western Canada
- 40 years of experience in Reinforcing Steel, fabrication, estimating, detailing, sales, safety, VP/COO business and facility operations.

**Participation in this course provides one (1) U/HSW/SD education credit**

Credit(s) earned on completion of this course will be reported to **AIA CES** for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

**As an AIA Passport Provider, CRSI will record AIA Member participation in courses.**

This course is registered with **AIA CES** for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

# Learning Objectives

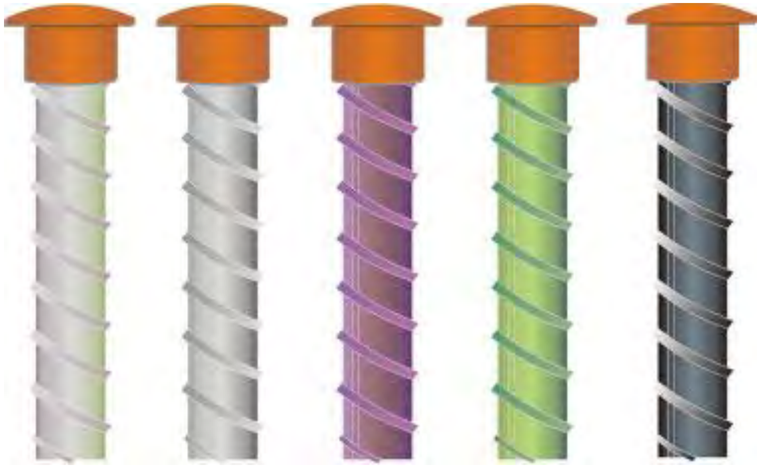
Upon completion of this program, participants will be able to:

1. Recognize Reinforcing Steel production processes from furnace to field.
2. Compare current Reinforcing Steel material availability, grades, sizes and material characteristics available in today's marketplace.
3. Compare appropriate Reinforcing Steel corrosion protection options, material splicing, and end anchors advancements as well as current applications used in today's marketplace.
4. Compare Reinforcing Steel costs relative to performances.
5. Source the technical information necessary to make informed design choices on an array of material choices.

# Reinforcing Steel Options for Concrete Construction

## Presentation Agenda

- Introduction to CRSI
- Rebar: History & Production
- Reinforcing Options
  - grades & strengths
  - coatings
  - availability
  - splicing
  - performance
  - cost
- Summary



# Introduction to CRSI

- resources
- members
- on-line

# What is CRSI?

CRSI

Concrete Reinforcing
Steel Institute

Founded in 1924, the Concrete Reinforcing Steel Institute (CRSI) is a technical institute and Standards Developing Organization (SDO) that stands as the authoritative resource for information related to steel reinforced concrete construction. CRSI offers many industry-trusted technical publications, standards documents, design aids, reference materials, and educational opportunities.

CRSI Members include manufacturers, fabricators, material suppliers, and placers of steel reinforcing bars and related products as well as professionals who are involved in the research, design, and construction of steel reinforced concrete structures and bridges

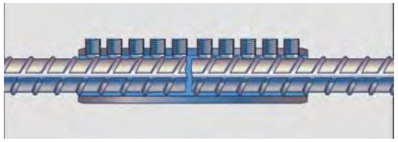
# Who Are CRSI's Members

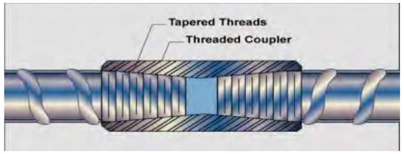
**Producers of Reinforcing Steel**

**Fabricators of Reinforcing Steel**

**Placers of Reinforcing Steel**

**Suppliers of related products & services**





# Members

INDUSTRY

Professional

- Reinforcing Steel Producers
- Reinforcing Steel Fabricators
- Reinforcing Steel Placers
- Splice, Anchorage, and Wire Manufacturers
- Reinforcing Detailers, Software Developers,
- and Equipment Manufacturers

- **Students**
- **Architects**
- **Engineers**
- **Contractors**
- **Subcontractors**
- **Inspectors**
- **Researchers**

CRSI Concrete Reinforcing Steel Institute

CRSI *Membership* | *Shop* CRSI | CRSI *Explorer*

*Services Finder* | *Case Studies* | CRSI *Concept*

# Professional Membership

Home > CRSI Membership > Join CRSI > Professional Membership

Resource Materials

Join CRSI +

Professional Membership

Student Membership

Members Only >

## Professional Membership

**Engineers, architects, code officials, building inspectors, specifiers, professors, and researchers are eligible for Professional membership in CRSI. Bookstores and resellers of any kind are not eligible. Benefits include:**

- COMPLIMENTARY copy of *Steel Reinforced Concrete: Essentials* ready reference guide (PDF version only).
- Savings on CRSI publications. Members may order three (3) copies of any publication every year at the member discount price.
- Discounted registration for all live and recorded webinars at our popular "Rebar U" e-learning site. *Each participant must be registered individually to receive a continuing education credit. Please note: Professional membership is based on an individual. Each individual from an organization must be a Professional member in order to receive maximum discounts. Some restrictions apply.*
- FREE and UNLIMITED project submittals in the CRSI HONORS design and construction awards recognition program.
- Information on CRSI activities.

Click here to purchase a Professional Membership online!

# CRSI Regional Managers

- Contact the CRSI Region Office in your area for more information

**Northeast Region**
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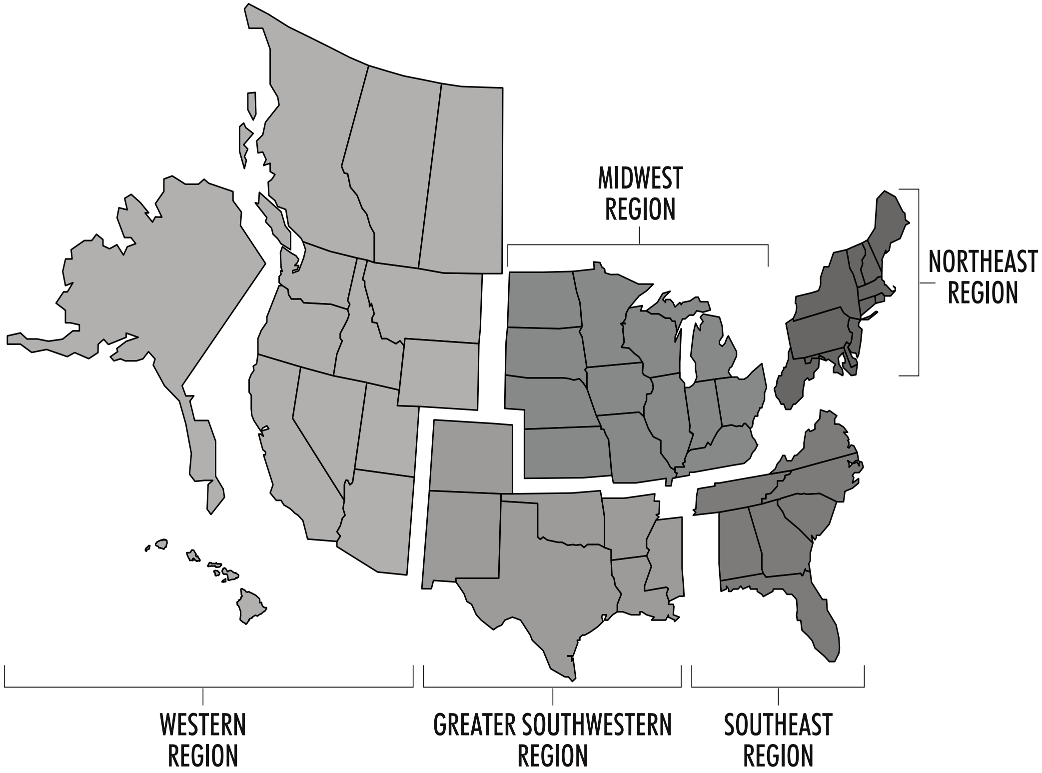
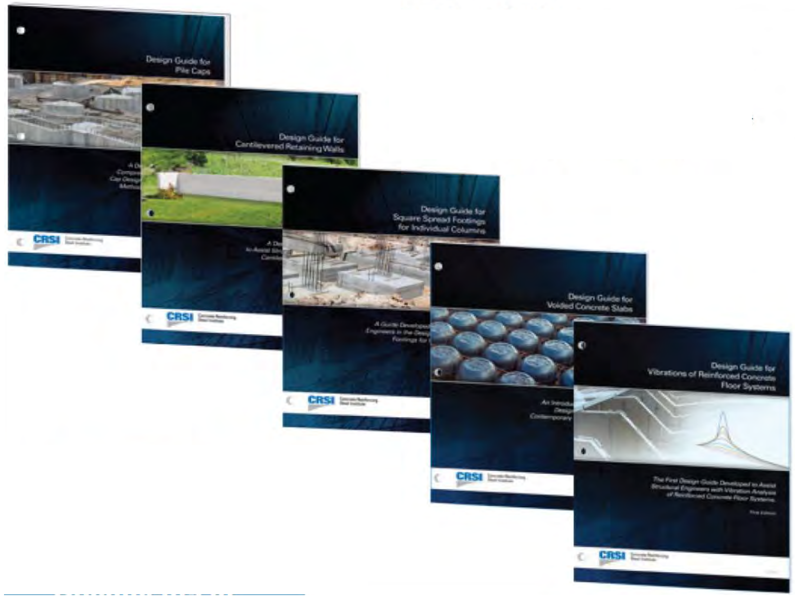


# Concrete Reinforcing Steel Institute

The trade association for the Reinforcing Steel Industry

**Founded in 1924**



**Represents Industry Members**

**Maintains Industry Standards**

**Provides Design and Construction Support**

**Promotes Reinforced Concrete Construction**

# CRSI TECHNICAL RESOURCES


**Available on [www.crsi.org](http://www.crsi.org)**
**In .pdf and print versions**

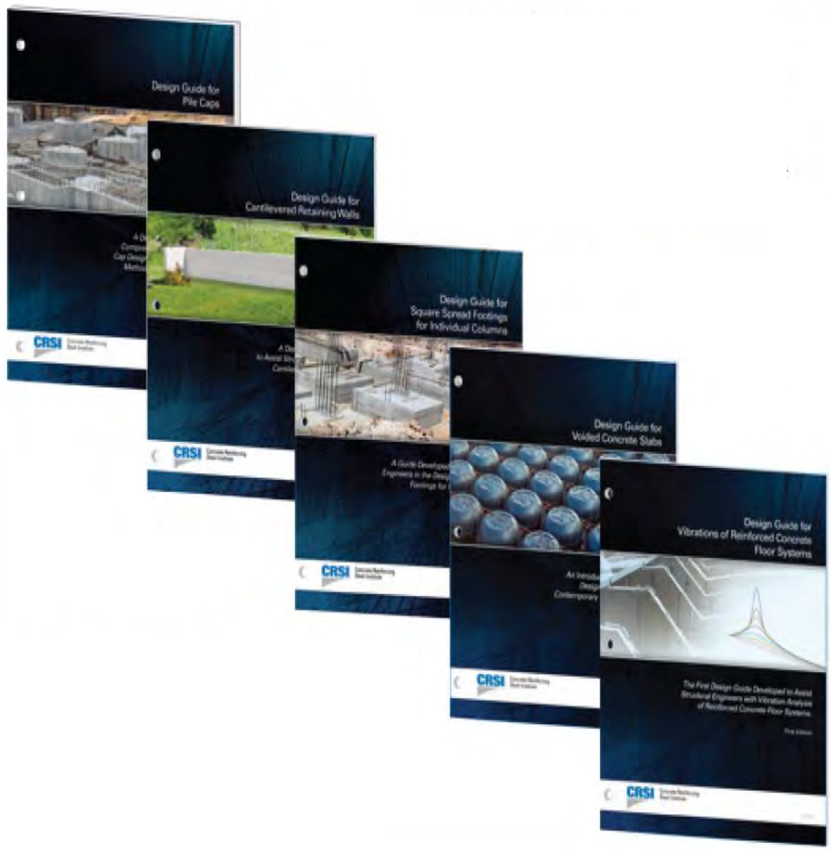
**Ranges from introductory to in-depth guidance and reference information on commonly used applications.**

- **Tech Briefs – over 50 introductory technical documents**
- **<u>Manual of Standard Practice</u>**
- **Design Guides – 10 in-depth subjects**
- **Field Inspection and Placement Manuals**
- **Industry Standards**
- **Research reports**
- **Rebar-U - On-line continuing education**

# Resources

- Case Studies
- Design Guides
- Detailing Supplements
- Engineering Data Reports
- Research Reports
- Standard Documents
- Technical Notes

# What are CRSI Design Guides?

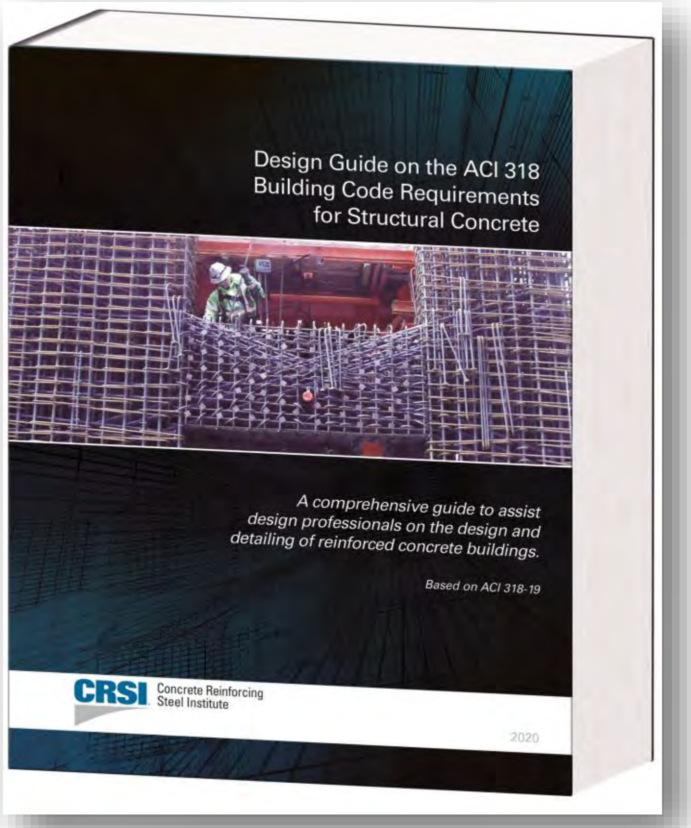



**Pile Caps (AASHTO)**
**Spread Footings**
**Retaining Walls**
**Economical Design**
**Voided Slabs**
**Floor Vibrations**
**Columns**
**Diaphragms**

**Available on**

- **PDF or**
- **Print**
- **www.crsi.org**

- Design Guide on the ACI 318 Building Code Requirements for Structural Concrete, CRSI, 2020
  - Cast-in-place concrete buildings with nonprestressed reinforcement
  - Chapters in the Design Guide are organized according to the chapters in ACI 318-19
  - 996 pages with over 140 worked-out examples with descriptive titles
  - Numerous details and design aids
  - Cross reference of section numbers in ACI 318-19 and page numbers in the Design Guide



# Resources

CRSI new Tech Notes on high strength steel covering :

- A615 Grade 80
- A615 grade 100
- Free to download at CRSI.org (resource materials)

ENGINEERING
ETN-D-7-20

Technical Note

## Guide to the Use of Grade 80 Reinforcing Bars in ACI 318-19

### Introduction

Grade 60 reinforcing steel, with a yield strength of 60,000 psi, is the most commonly used grade in North America. Recent advances, including substantial new research, have enabled reinforcing steels of higher strengths to be a viable option in a variety of applications in reinforced concrete structures.

Permissible applications of high-strength steel reinforcement (that is, reinforcement with a yield strength of 80,000 or 100,000 psi) were significantly expanded in the 2019 edition of *Building Code Requirements for Structural Concrete and Commentary* (ACI 2019). The purpose of this Technical Note is to summarize the requirements in ACI 318-19 related to Grade 80 reinforcing bars. Industry professionals should find the information useful when designing, detailing, and specifying Grade 80 reinforcing bars in building projects. Benefits related to the use of Grade 80 reinforcing bars are also included.

Information on the design and detailing of cast-in-place reinforced concrete buildings with high-strength steel reinforcement, including worked-out design examples, can be found in *Design Guide on the ACI 318 Building Code Requirements for Structural Concrete – ACI 318-19* (CRSI 2020).

### Types of Nonprestressed Grade 80 Reinforcing Bars

Grade 80 deformed reinforcing bars must conform to the following specifications (ACI 20.2.1.3):[1]

- ASTM A615 (ASTM 2018a) – carbon steel, including the requirements in ACI Table 20.2.1.3(a)
- ASTM A706 (ASTM 2016a) – low-alloy steel, including the requirements in ACI 20.2.1.3(c)
- ASTM A955 (ASTM 2018b) – stainless steel

Similarly, Grade 80 plain reinforcing bars for spiral reinforcement must conform to the following specifications (ACI 20.2.1.4):

- ASTM A615 (ASTM 2018a)
- ASTM A706 (ASTM 2016a)
- ASTM A955 (ASTM 2018b)

Bar sizes larger than #18 are given in current editions of ASTM A615 and ASTM A1035. Due to the lack of information on their performance (including bar bends and the determination of development lengths), bar sizes larger than #18 are not permitted by ACI 318-19 (ACI R20.2.1.3).

New property requirements are given in ACI Table 20.2.1.3(a) for ASTM A615 Grade 80 deformed reinforcing bars and in ACI Table 20.2.1.3(c) for ASTM A706 Grade 80 deformed reinforcing bars (see Tables 1 and 2, respectively). These requirements are not included in the 2018 edition of ASTM A615 and the 2016 edition of ASTM A706, which are the referenced specifications in ACI 318-19 (see ACI 3.2.4).[2]

Bend test requirements for ASTM A706 Grade 80 reinforcement are given in the latest version of that specification (ASTM 2016a). [Note: Due to potential safety concerns with shop fabrication, CRSI does not recommend bending reinforcing bars larger than #14 with a grade designation of Grade 75 or higher.]

The following new requirement was introduced for all grades of ASTM A706 deformed reinforcing bars [ACI 20.2.1.3(b)(iii)]: The radius on newly-machined rolls used to manufacture reinforcing bars must be at least 1.5 times the height of the deformation, h (see Figure 1). This requirement applies to all deformations, including transverse lugs, longitudinal ribs, grade ribs, grade marks, and intersections between deformations. Conformation is assessed by measurements taken on newly-machined rolls used to manufacture

[1] *Disclaimer: This CRSI document contains requirements that can, at the time of the document's adoption by CRSI, be satisfied only by use of a patented material, product, process, procedure, or technology. During the document preparation, the Engineering Practice Committee (EPC) was informed in writing that the document under consideration involves the potential use of patented technology. The specific patented product being referenced include certain stainless steel alloys listed in Table 1 of ASTM A276.*

[2] *It is anticipated that the requirements in ACI 20.2.1.3 will appear in the 2020 editions of ASTM A615 and ASTM A706.*

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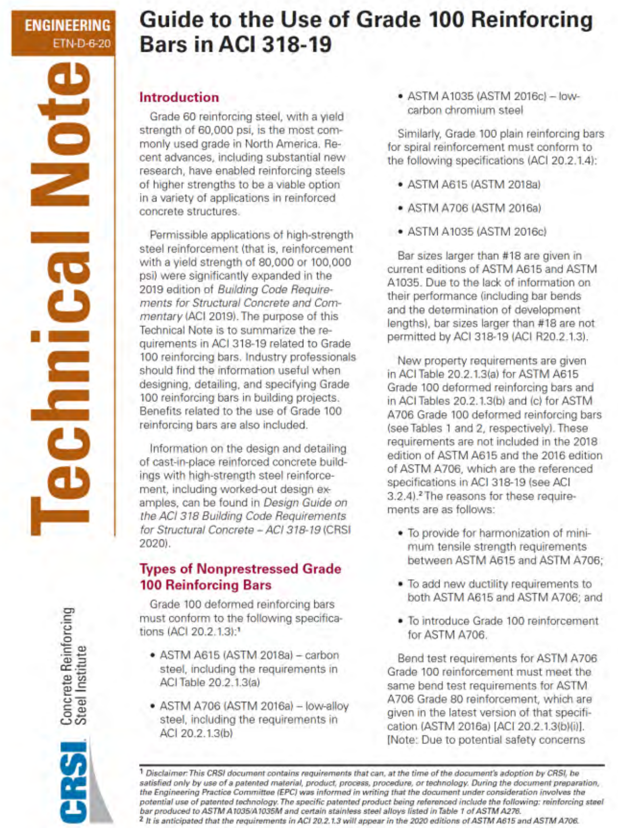

ENGINEERING
ETN-D-6-20

Technical Note

## Guide to the Use of Grade 100 Reinforcing Bars in ACI 318-19

### Introduction

Grade 60 reinforcing steel, with a yield strength of 60,000 psi, is the most commonly used grade in North America. Recent advances, including substantial new research, have enabled reinforcing steels of higher strengths to be a viable option in a variety of applications in reinforced concrete structures.

Permissible applications of high-strength steel reinforcement (that is, reinforcement with a yield strength of 80,000 or 100,000 psi) were significantly expanded in the 2019 edition of *Building Code Requirements for Structural Concrete and Commentary* (ACI 2019). The purpose of this Technical Note is to summarize the requirements in ACI 318-19 related to Grade 100 reinforcing bars. Industry professionals should find the information useful when designing, detailing, and specifying Grade 100 reinforcing bars in building projects. Benefits related to the use of Grade 100 reinforcing bars are also included.

Information on the design and detailing of cast-in-place reinforced concrete buildings with high-strength steel reinforcement, including worked-out design examples, can be found in *Design Guide on the ACI 318 Building Code Requirements for Structural Concrete – ACI 318-19* (CRSI 2020).

### Types of Nonprestressed Grade 100 Reinforcing Bars

Grade 100 deformed reinforcing bars must conform to the following specifications (ACI 20.2.1.3):[1]

- ASTM A615 (ASTM 2018a) – carbon steel, including the requirements in ACI Table 20.2.1.3(a)
- ASTM A706 (ASTM 2016a) – low-alloy steel, including the requirements in ACI 20.2.1.3(b)
- ASTM A1035 (ASTM 2016c) – low-carbon chromium steel

Similarly, Grade 100 plain reinforcing bars for spiral reinforcement must conform to the following specifications (ACI 20.2.1.4):

- ASTM A615 (ASTM 2018a)
- ASTM A706 (ASTM 2016a)
- ASTM A1035 (ASTM 2016c)

Bar sizes larger than #18 are given in current editions of ASTM A615 and ASTM A1035. Due to the lack of information on their performance (including bar bends and the determination of development lengths), bar sizes larger than #18 are not permitted by ACI 318-19 (ACI R20.2.1.3).

New property requirements are given in ACI Table 20.2.1.3(a) for ASTM A615 Grade 100 deformed reinforcing bars and in ACI Tables 20.2.1.3(b) and (c) for ASTM A706 Grade 100 deformed reinforcing bars (see Tables 1 and 2, respectively). These requirements are not included in the 2018 edition of ASTM A615 and the 2016 edition of ASTM A706, which are the referenced specifications in ACI 318-19 (see ACI 3.2.4).[2] The reasons for these requirements are as follows:

- To provide for harmonization of minimum tensile strength requirements between ASTM A615 and ASTM A706;
- To add new ductility requirements to both ASTM A615 and ASTM A706; and
- To introduce Grade 100 reinforcement for ASTM A706.

Bend test requirements for ASTM A706 Grade 100 reinforcement must meet the same bend test requirements for ASTM A706 Grade 80 reinforcement, which are given in the latest version of that specification (ASTM 2016a) [ACI 20.2.1.3(b)(i)]. [Note: Due to potential safety concerns

[1] *Disclaimer: This CRSI document contains requirements that can, at the time of the document's adoption by CRSI, be satisfied only by use of a patented material, product, process, procedure, or technology. During the document preparation, the Engineering Practice Committee (EPC) was informed in writing that the document under consideration involves the potential use of patented technology. The specific patented product being referenced include the following: reinforcing steel bar produced to ASTM A1035/A1035M and certain stainless steel alloys listed in Table 1 of ASTM A276.*

[2] *It is anticipated that the requirements in ACI 20.2.1.3 will appear in the 2020 editions of ASTM A615 and ASTM A706.*

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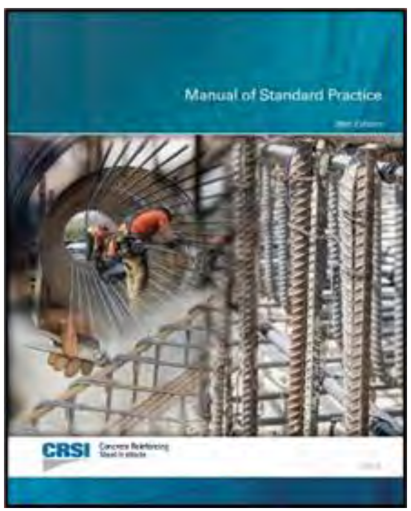
# Reinforcing Steel Resources

## Essential CRSI Publications

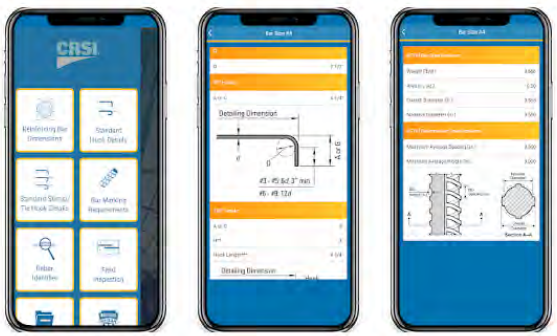





# CRSI Mobile App

- Development lengths module
  - ACI 318-19
  - AASHTO 8th Edition

- Apple iOS:
  - https://apps.apple.com/us/app/crsi-rebar-reference/id1423271565?ls=1
- Google Android
  - https://play.google.com/store/apps/details?id=org.crsi.rrr



# CRSI Honors Award

## 2020 Winner

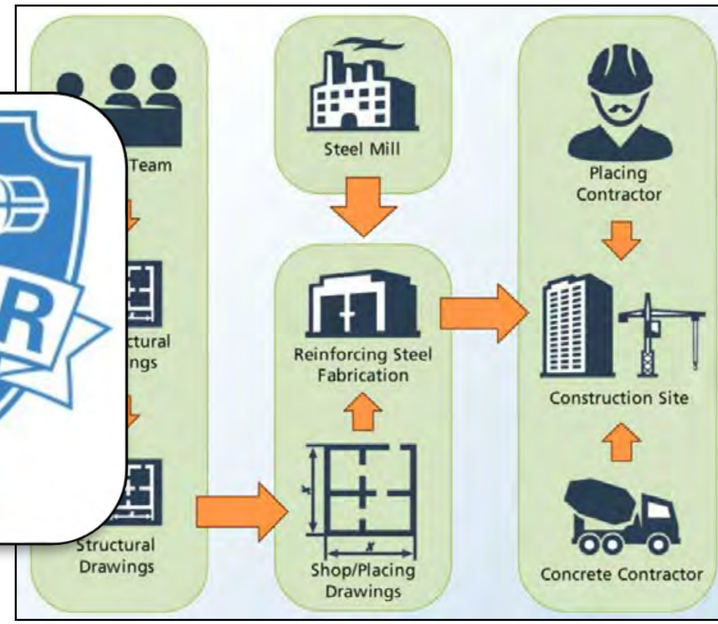
Honors Award, BASE Engineering. Transportation for the Consolidated Car Facility (Kahului Airport, Maui, Hawaii)

# e-Learning

## On-Demand Webinars

## Interactive Courses

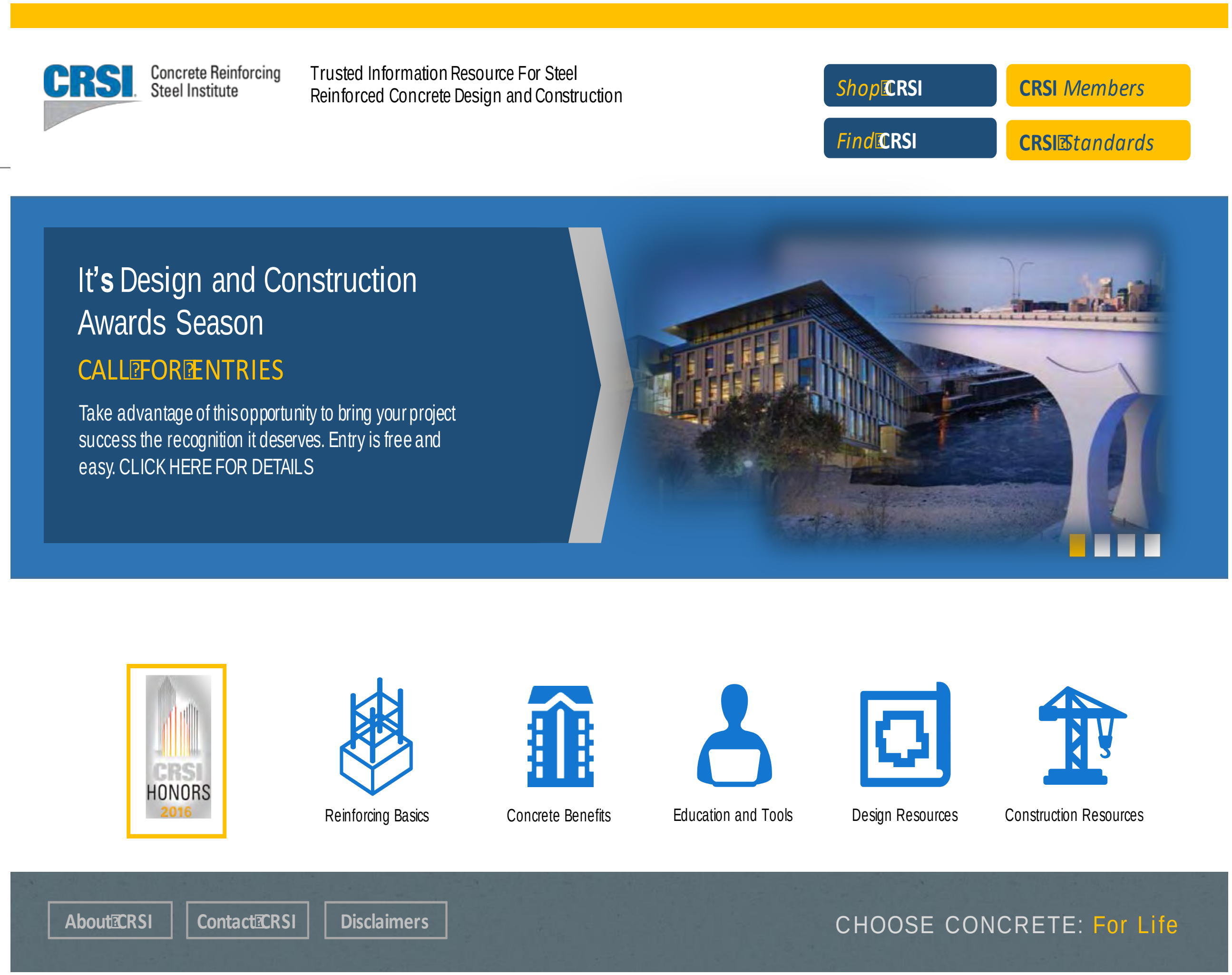
*High-Strength Steel Reinforcement*




*Steel Reinforced Concrete: Essentials*

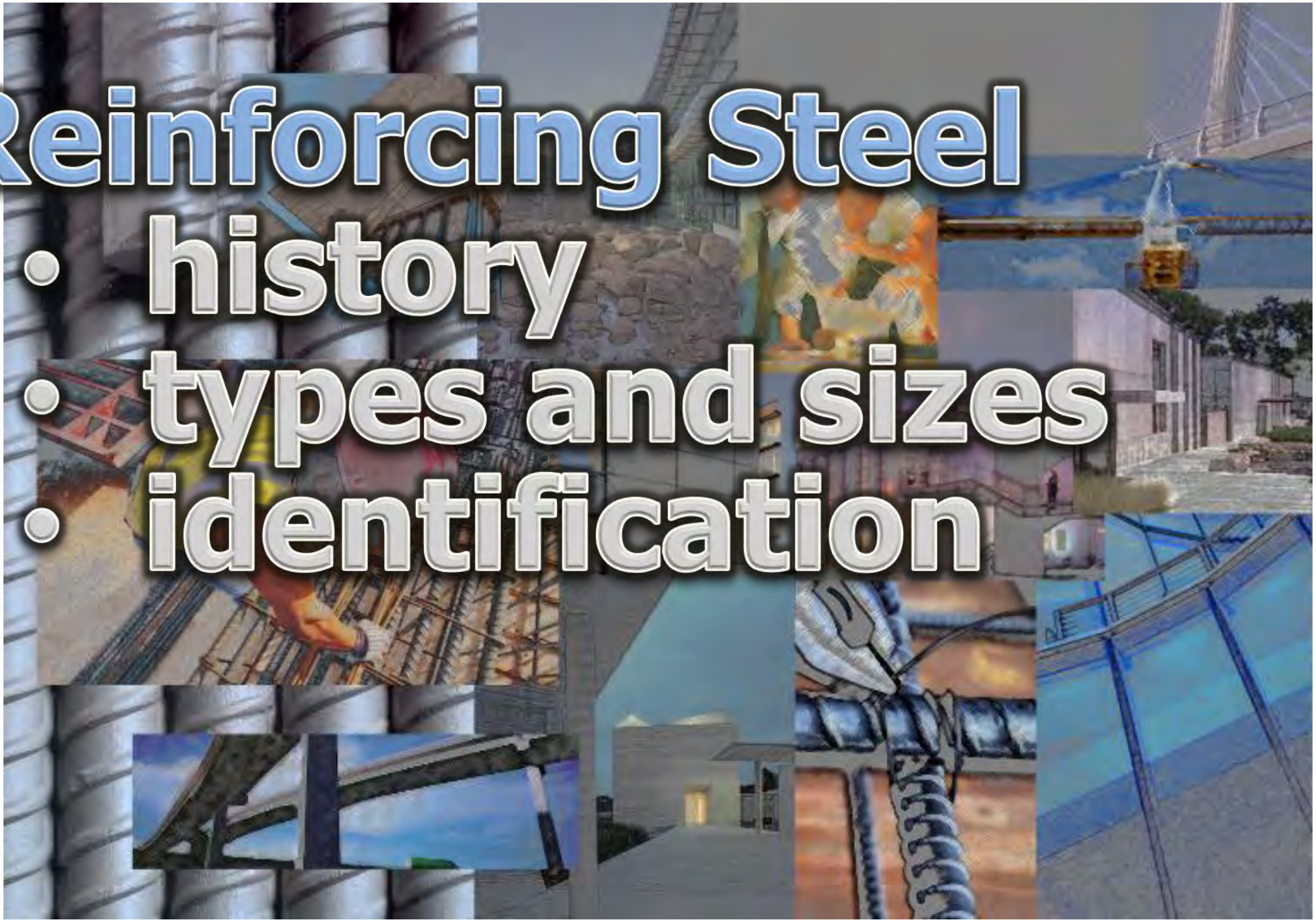
www.crsi.org

# Look to CRSI for answers to your reinforced concrete questions at www.crsi.org



# Reinforcing Steel

- history
- types and sizes
- identification



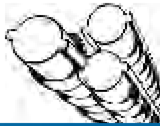
# History of Early Rebar

First reinforced concrete structures in 1884

- Size and strength
  - 1911 to 1927: Grade 33
  - 1911 to 1966: Grade 50
  - 1928 to 1963: Grade 40
- Bond and deformations
  - early 1950’s from square to round
  - smooth, round, twisted, deformed
  - rule: development length is 2X current
  - hooks provided ½ development

# Bar Sizes

| BAR SIZE DESIGNATION | NOMINAL DIMENSIONS | | |
|---|---|---|---|
| | AREA ($in.^2$) | WEIGHT (lb/ft) | DIAMETER (in.) |
| #3 | 0.11 | 0.376 | 0.375 |
| #4 | 0.20 | 0.668 | 0.500 |
| #5 | 0.31 | 1.043 | 0.625 |
| #6 | 0.44 | 1.502 | 0.750 |
| #7 | 0.60 | 2.044 | 0.875 |
| #8 | 0.79 | 2.670 | 1.000 |
| #9 | 1.00 | 3.400 | 1.128 |
| #10 | 1.27 | 4.303 | 1.270 |
| #11 | 1.56 | 5.313 | 1.410 |
| #14 | 2.25 | 7.65 | 1.693 |
| #18 | 4.00 | 13.60 | 2.257 |
| #20 | 4.91 | 16.69 | 2.50 |



# Bar Markings


**Grade 60 shown**

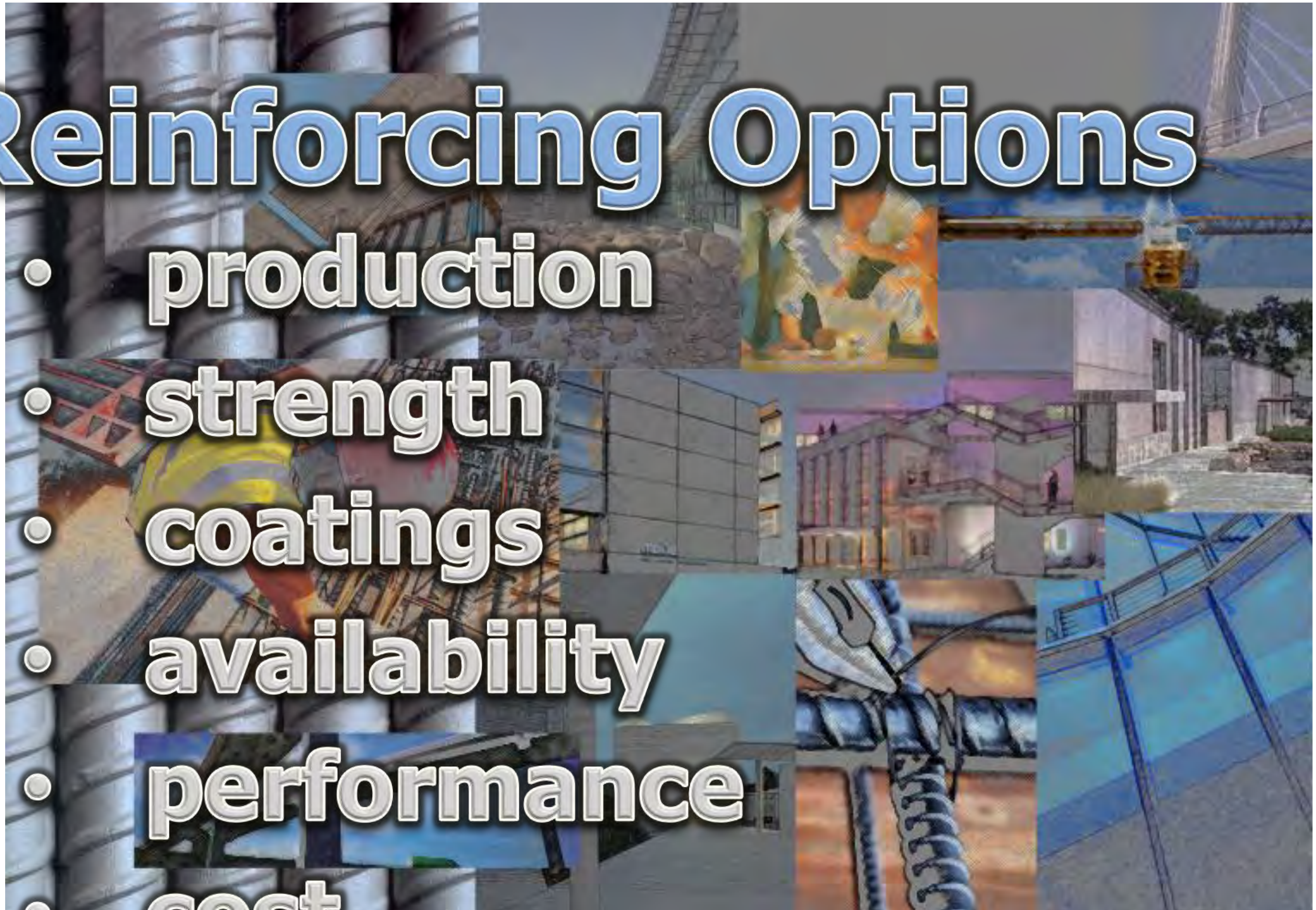
Grade 40 – No grade markings
Grade 60 – 60
Grade 75 – 75
Grade 80 – 80
Grade 100 – 100
Grade 120 – 120

* Steel Types

S–for Carbon-Steel (A615)
A–for Axle-Steel (A996)
W–for Low-Alloy Steel (A706)
SS–for Stainless Steel (A955)
CS–for Low-Carbon Chromium (A1035)

**Bars marked with S and W meet both A615 and A706*

# Reinforcing Options

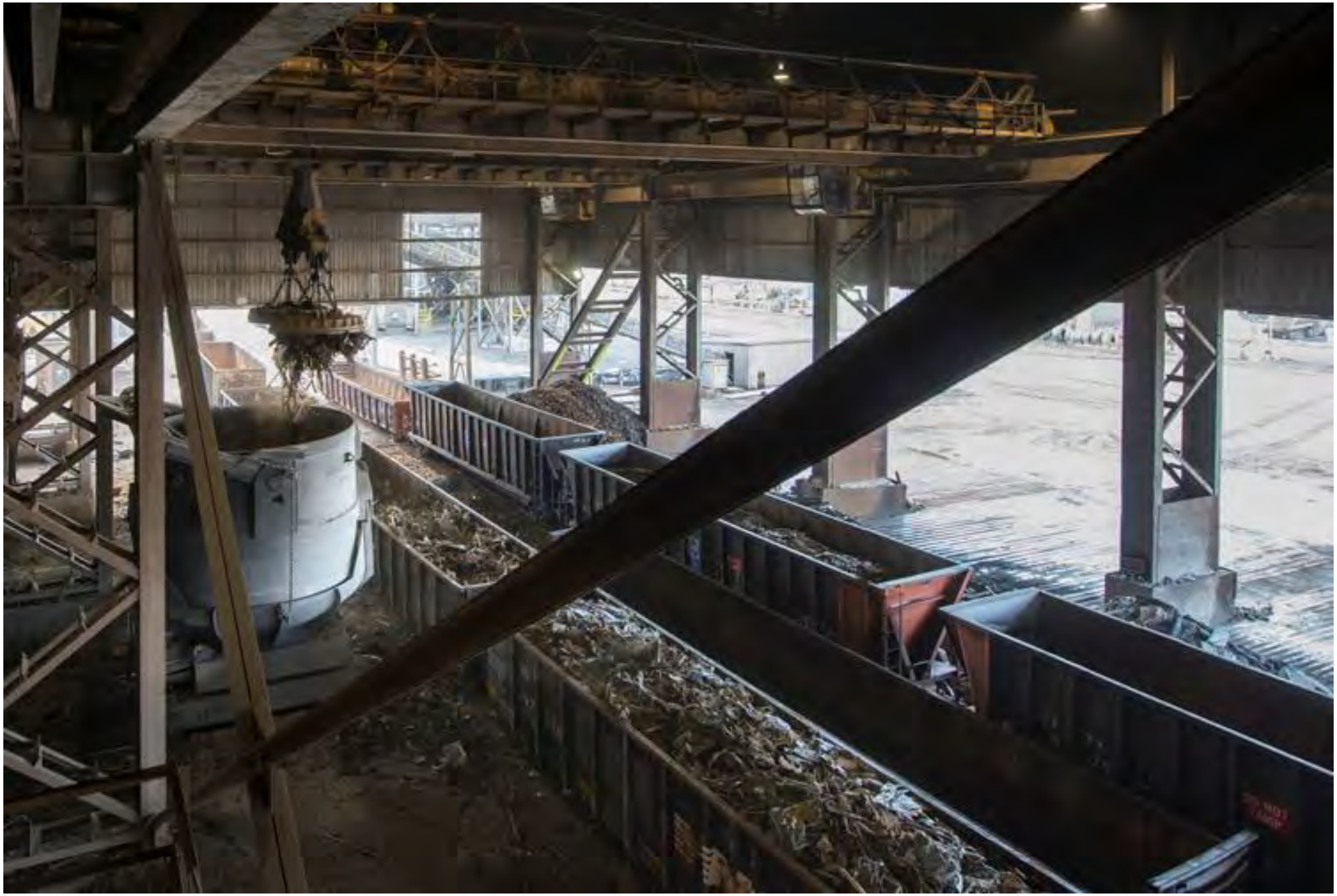


- production
- strength
- coatings
- availability
- performance
- cost

# Rebar Production

## RECYCLED AND RECYCLE-ABLE

Nearly 98%
Recycled
Post-Consumer
Components



## Furnace

## Laddle & Tundish

## Billet Stock

# REBAR ROLLING PROCESS

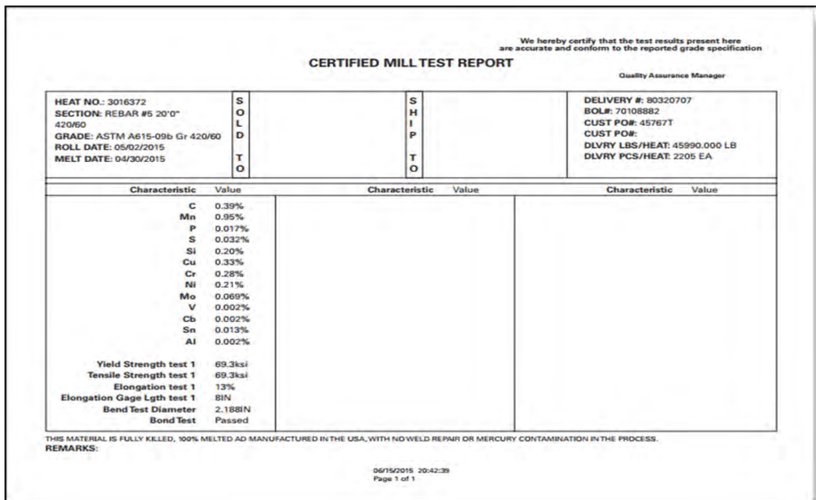
Courtesy, Cascade Steel Rolling Mills, McMinnville OR

## Straight Bar Stock vs Coiled or Spooled Stock

# Material Identification

- Whole, unbroken bundles, tagged from mill
- ID tag attached to each bundle
- Bundle has Mill Test Report ID (Heat Number)

# Mill Test Report



We hereby certify that the test results present here
are accurate and conform to the reported grade specification

**CERTIFIED MILL TEST REPORT**

Quality Assurance Manager

**HEAT NO.:** 3016372
**SECTION:** REBAR #5 20'0"
420/60
**GRADE:** ASTM A615-09b Gr 420/60
**ROLL DATE:** 05/02/2015
**MELT DATE:** 04/30/2015

SOLD TO

SHIP TO

**DELIVERY #:** 80320707
**BOL#:** 70108882
**CUST PO#:** 45767T
**CUST PO#:**
**DLVRY LBS/HEAT:** 45990.000 LB
**DLVRY PCS/HEAT:** 2205 EA

| Characteristic | Value | Characteristic | Value | Characteristic | Value |
|---|---|---|---|---|---|
| C | 0.39% | | | | |
| Mn | 0.95% | | | | |
| P | 0.017% | | | | |
| S | 0.032% | | | | |
| Si | 0.20% | | | | |
| Cu | 0.33% | | | | |
| Cr | 0.28% | | | | |
| Ni | 0.21% | | | | |
| Mo | 0.069% | | | | |
| V | 0.002% | | | | |
| Cb | 0.002% | | | | |
| Sn | 0.013% | | | | |
| Al | 0.002% | | | | |
| Yield Strength test 1 | 69.3ksi | | | | |
| Tensile Strength test 1 | 69.3ksi | | | | |
| Elongation test 1 | 13% | | | | |
| Elongation Gage Lgth test 1 | 8IN | | | | |
| Bend Test Diameter | 2.188IN | | | | |
| Bond Test | Passed | | | | |

THIS MATERIAL IS FULLY KILLED, 100% MELTED AD MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.
**REMARKS:**

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Page 1 of 1

- **Manufacturing Date, Heat Number, Product, Grade of product**
- **Chemical analysis (C, Mn, P, S, Si, Cu, Cr, Ni, Mo, V, Sn, Al, N)**
- **Yield, Tensile & Elongation**
- **% on nominal weight variance**
- **Bend test and unit of measure**
- **Melt & Roll dates, weight of Heat**

**Mill Test Reports – MTR's are generally mailed after fabrication and delivery.**

# Reinforcing Steel Today

| | |
|---|---|
| A-615 | Carbon Steel |
| A-706 | Weld Specification |
| A-767 | Galvanized – Hot Dipped |
| A-775 | Epoxy Coated |
| A-934 | Epoxy Coated |
| A-1094 | Galvanized |
| A-955 | Stainless |
| A-1035 | Low-Carbon-Chromium |

# A-615 (Carbon Steel)


## BAR PROPERTIES

This specification covers deformed and plain carbon-steel bars for concrete reinforcements in cut lengths and coils.  Materials considered under this specification are available in Grades 40 [280], 60 [420], 75 [520], 80 [550], and 100 [690].

# ASTM A615 Steel

| <u>ASTM A615</u> | Grade 60 (Grade 420) | Grade 80 (Grade 550) | Grade 100 (Grade 690) |
|---|---|---|---|
| Minimum Yield Strength, psi (MPa) | 60,000 (420) | 80,000 (550) | 100,000 (690) |
| Minimum Tensile Strength, psi (MPa) | 80,000 (550) | 105,000 (725) | 115,000 (790) |
| Bar Designation | Minimum Percent Elongation in 8” | | |
| #3 | 9 | 7 | 7 |
| #4, #5, #6 | 9 | 7 | 7 |
| #7, #8 | 8 | 7 | 7 |
| #9, #10, #11, #14, #18, #20 | 7 | 6 | 6 |

* Previously 90,000

Information pertaining to Grade 75 reinforcing can now be found in the ASTM A-615 Appendix.

# Availability – A615

## Grade 80 versus Grade 60

- use in shear walls, columns, foundations, and beams
- generally larger bar, but may get all sizes
- no minimums, but may need lead time
- mill cost premiums apply
- can result in significant material and labor cost savings
- Straight and Coil Stock (mill dependent)

# A-706 (Weldable)


## BAR PROPERTIES

This specification covers deformed and plain low-alloy steel bars in cut lengths or coils for concrete reinforcement intended for specific applications. Restrictive mechanical properties and chemical composition are required for compatibility with controlled tensile property applications or to enhance weldability.

# ASTM A706 Steel

| ASTM A706 | Grade 60 (Grade 420) | Grade 80 (Grade 550) |
|---|---|---|
| Minimum Yield Strength, psi (MPa) | 60,000 (420) | 80,000 (550) |
| Maximum Yield Strength, psi (MPa) | 78,000 (540) | 98,000 (675) |
| Minimum Tensile Strength, psi (MPa) | 80,000 (550) | 100,000 [A] (690) |
| Bar Designation | Minimum Percent Elongation in 8” | |
| #3, #4, #5, #6 | 14 | 12 |
| #7, #8, #9, #10, #11 | 12 | 12 |
| #14, #18 | 10 | 10 |

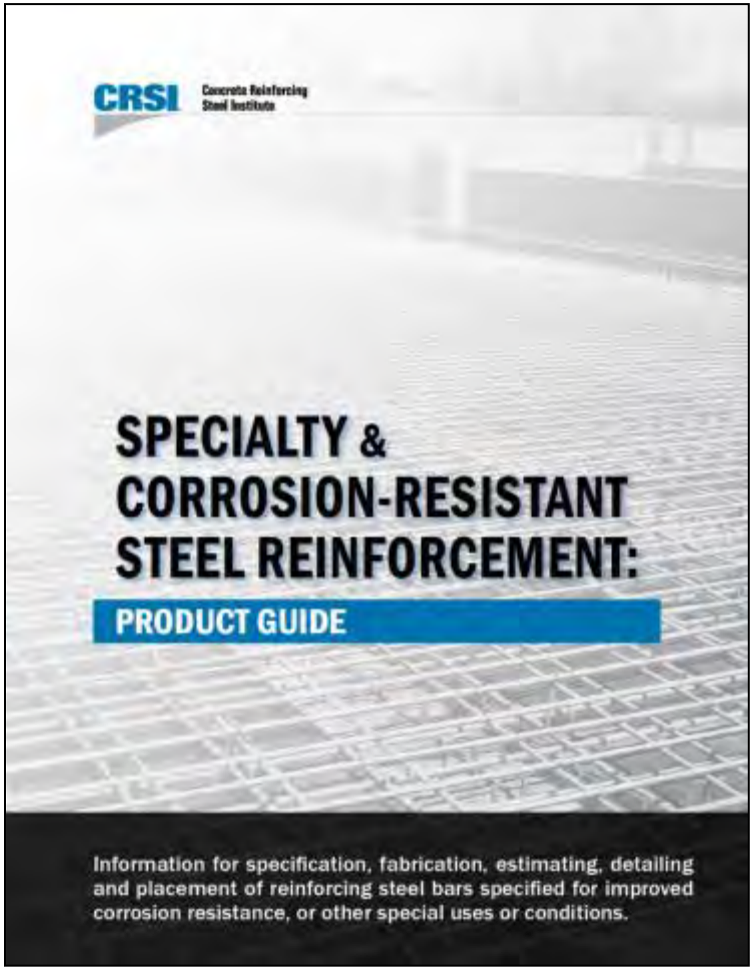
[A] Tensile strength shall not be less than 1.25 times the actual yield strength.

# Availability – A706

## A706 versus A615

- low-alloy - lower carbon content
- welding steel
- tighter strength limits with yield strength not to exceed 18 ksi above minimum fy
- used where greater ductility is required
- available -- small premium compared to A615 bars
- Most mills can produce a dual grade A615/A706

# Specialty Rebar Information




- Definitions
- Usage
- Standards
- Epoxy-coated
- Galvanized
- Dual-coated
- Stainless
- Low carbon, chromium

# A-767 (Galvanized)


## BAR PROPERTIES

This specification covers steel reinforcing bars with protective zinc coatings applied by dipping the properly prepared reinforcing bars into a molten bath of zinc. Galvanization shall be used to prepare reinforcing bars.

# Galvanized Reinforcing

ASTM A767 (hot dipped)

- Sheared and bent *before* coating

Develop oxide layer for protection

- dependent on cement and zinc chemistry
- microstructure may significantly affect performance

# Galvanized Reinforcing

ASTM A1094 (in line application)

- Sheared and bent *after* coating

Develop oxide layer for protection

- dependent on cement and zinc chemistry
- microstructure may significantly affect performance

# A-775 (Epoxy)


## BAR PROPERTIES

This specification covers deformed and plain steel reinforcing bars with protective epoxy coating applied in line by the electrostatic spray method prior to fabrication.

# A-934 (Epoxy)


## BAR PROPERTIES

This specification covers deformed and plain steel reinforcing bars which prior to surface preparation are prefabricated and then coated post fabrication with a protective fusion-bonded epoxy coating by electrostatic spray or other suitable method.

# Epoxy-Coated Reinforcement

Accounts for ~9 percent of all reinforcing steel

A-775: Green

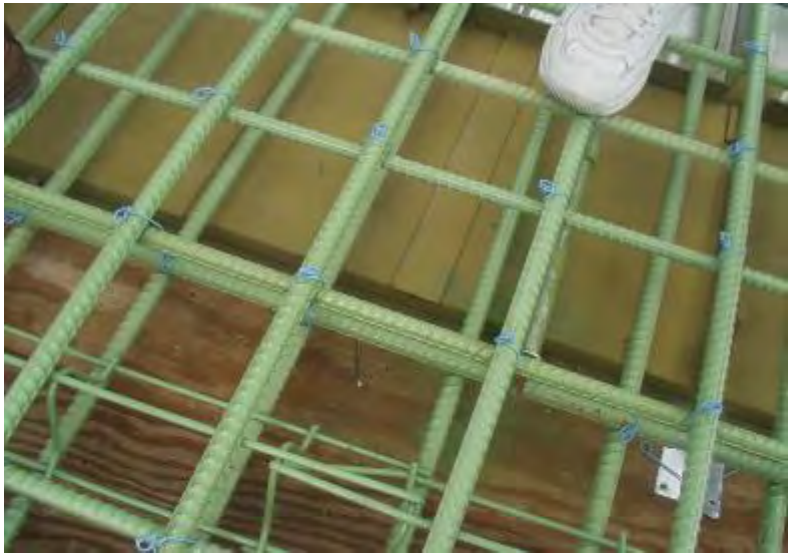
- bent after coating
- most widely used and researched material
- significant material improvements over nearly 50 years
- Over 80,000 bridges

A-934: Purple or Gray

- bent before coating

# Handling Epoxy-Coated Bars

- Use nylon slings or other padded material to lift and transport bars
- Lift and set bars into place
  - bars should never be dragged into place
- Minimize walking on bars after placement
- Bars to be visually inspected for damage after placement



# A-955 (Stainless)


## BAR PROPERTIES

This specification covers deformed and plain Stainless-Steel bars for concrete reinforcement proposed to be used in applications requiring corrosion resistance or controlled magnetic permeability.

# Stainless Steel

Stainless steel reinforcing bars are experiencing increased use in reinforced **concrete projects because of the material's** inherent properties.

Depending upon the chemistry specified, these properties may include

- *corrosion resistance,*
- *low magnetic permeability,*
- *ductility,*
- *or a combination thereof.*

# Stainless Properties

- Must contain a minimum chromium (Cr) content of 10.5 percent and a maximum carbon (C) content of 1.20 percent.
- Stainless steel-clad reinforcement consists of a thin layer of stainless steel over carbon steel.
- Can be fabricated into the entire array of standard CRSI and ACI bend shapes.
- ACI and AASHTO generally treat stainless steel reinforcing bars the same as carbon steel reinforcing bars in terms of structural design.

# Stainless Availability

- Available in Grades 60 (420) ,75 (520) and recently added Grade 80 (550)
- Bars #3 through #6 can be produced into coils for fabrication.
- Bars #4 - #11 are typically available in 60 ft. straight lengths (inquire for lengths).
- Available through several domestic and foreign steel mills.
- Currently no producers of stainless-steel clad reinforcement in North America.

# A-1035 (MMFX)


## BAR PROPERTIES

This specification covers low-carbon, chromium, steel bars, deformed and plane for concrete reinforcement in cut lengths and coils. Grade 100 & 120. ChromX is the recognized brand name.

**Today's Trivia Question**

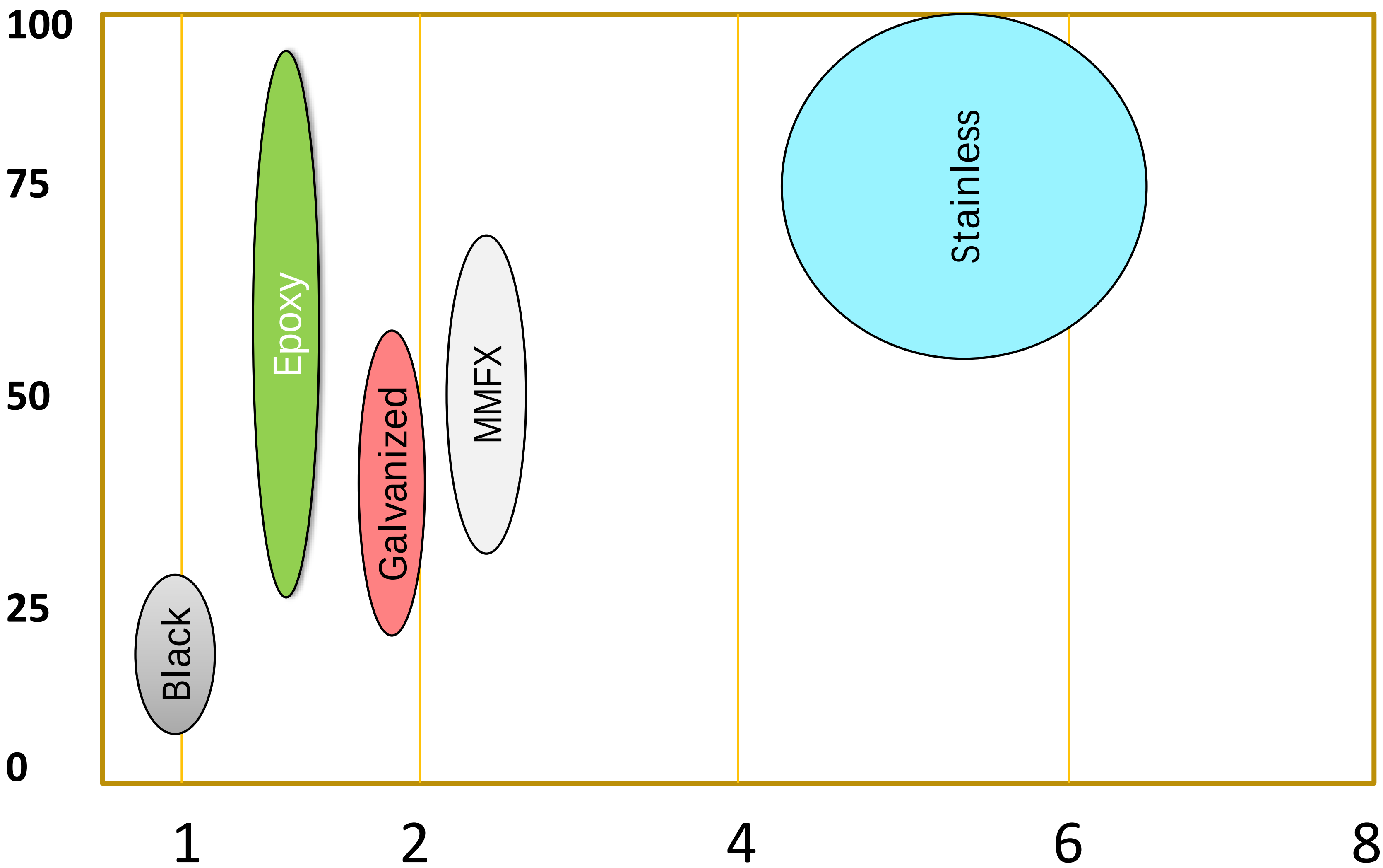
What does MMFX stand for?
*Multiphased Martensitic Formable Steel*

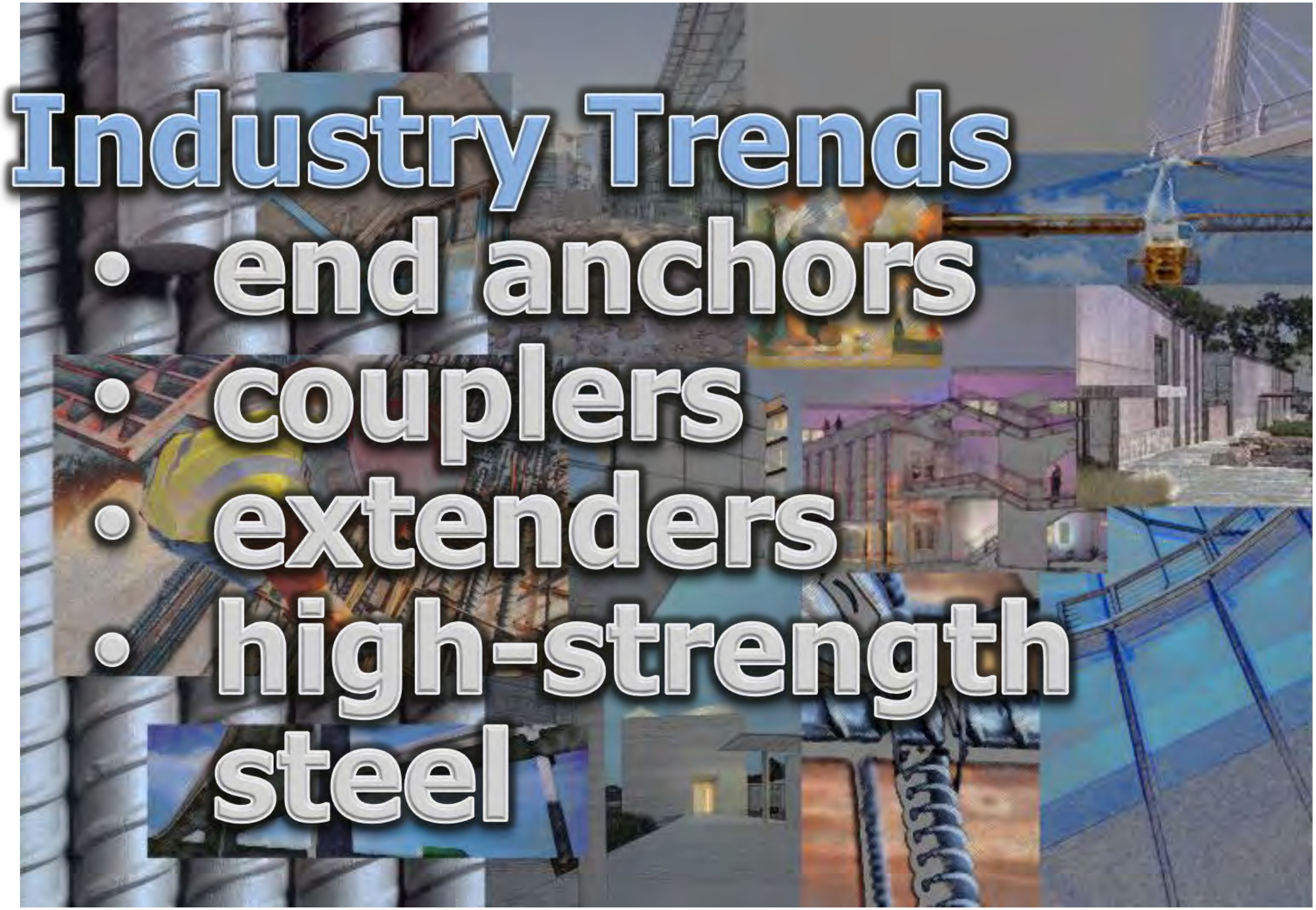
# Metallurgical Properties of Ultra-High-Strength Steel

How is ultra-high-strength steel achieved?

- quenching and tempering
  - quenches surface layer and pressurizes intermediate layers
- thermo-mechanical treatment (TMT)
  - strain hardening/cold work and heat treatment
- addition of vanadium (expensive)

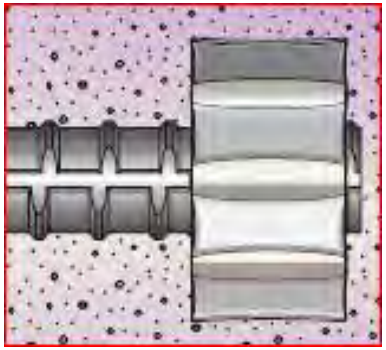
# Performance vs. Relative Cost




Industry Trends
• end anchors
• couplers
• extenders
• high-strength steel

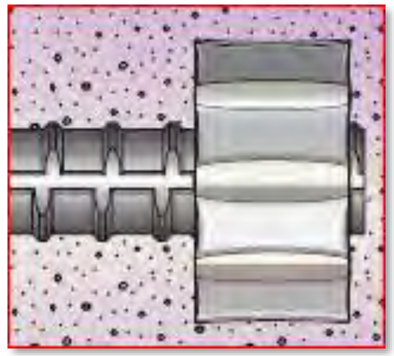
# End Anchors

- Replaces conventional hooks
- Simplifies bar placement at beam to column joints
- Reduces bar congestion
- Allows greater design flexibility

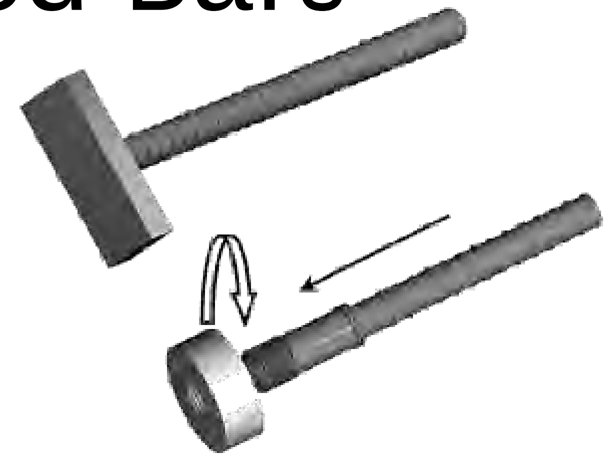


# Also Known as Headed Bars

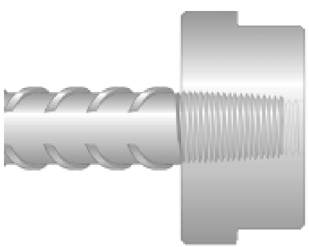
**Parallel Thread**



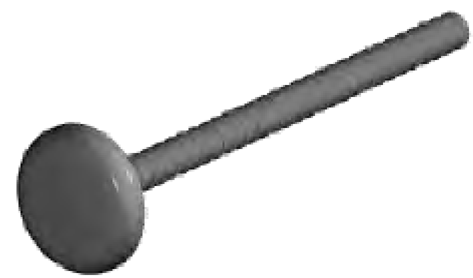
**Swaged**



**Friction Welded**



**Tapered Thread**



**Integrally Forged**

# Benefits

- Shorter basic tension development length
- Ease of placement and installation in highly congested areas
- Easier to insert or "fish" the longitudinal bar in a cage during construction.
- Since headed bars don't protrude as much as hooks there is less impact on cover constraints

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ETN-M-3-14

Technical Note

# Frequently Asked Questions (FAQ) About Headed Reinforcing Bars

a) At top of column.

b) At the end of a beam.

Figure 1 — Typical examples of headed bar usage in building structures.

## Introduction

Headed deformed reinforcing bars are in increasing demand for use in reinforced concrete projects for a variety of reasons. Headed deformed bars reduce reinforcing bar congestion where terminating bars with 90 or 180 degree hooks are needed. Such regions where termination is difficult include, but are not limited to, beam-column joints, beam ends, and corbels. Figure 1 illustrates some common uses of headed reinforcing bars where considerable congestion would exist if hooked bars were used. Headed bar use has also been on the rise as acceptance of strut-and-tie analysis modeling techniques, permitted in the ACI 318 Building Code [ACI 2011], receive greater acceptance by the design profession.

CRSI routinely receives inquiries concerning various aspects of reinforcing bars, reinforced concrete design, and reinforced concrete construction. Most of these inquiries originate from design professionals (engineers and architects) and field personnel (inspectors, code enforcement personnel, and contractors). This Technical Note presents a collection of questions frequently asked regarding headed reinforcing bars. It should be noted that typical headed bar questions vary by region, manufacturer, and project type.

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# Headed Bars in Beams

# Headed Bars in Columns

# Grade 80 & 100 Headed Bars

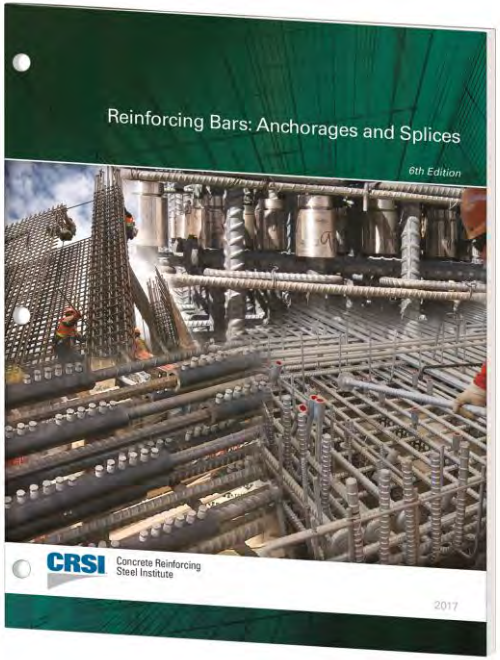
# Headed Bar Benefits

- Mitigate Rebar Congestion
- Better consolidation
- Faster construction
- Use for unknown pile tip elevation
- Field or Shop installation

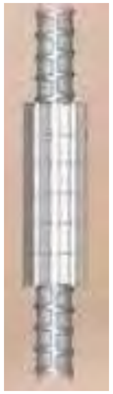
## Reinforcing Bars: Anchorages and Splices

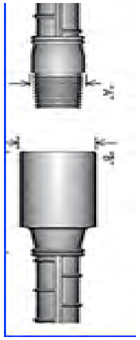
Table of Contents:





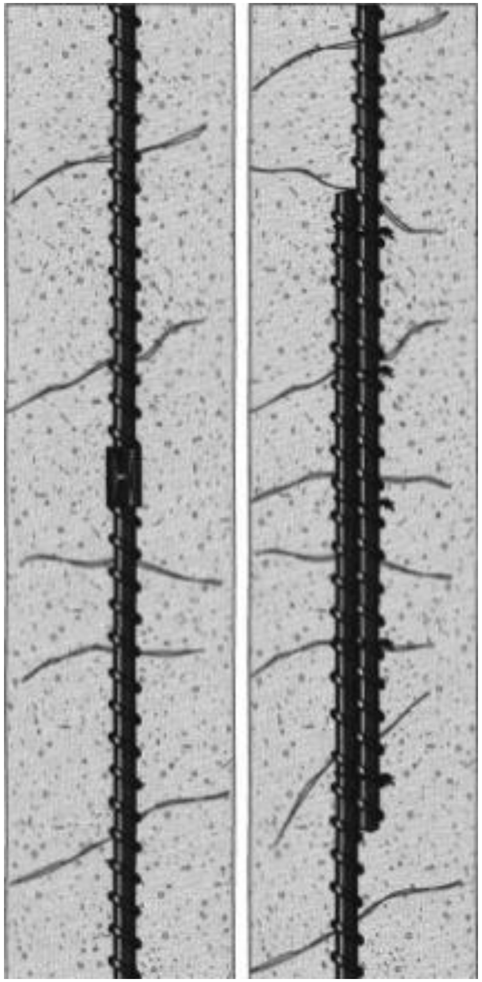
# Mechanical Splices or Couplers





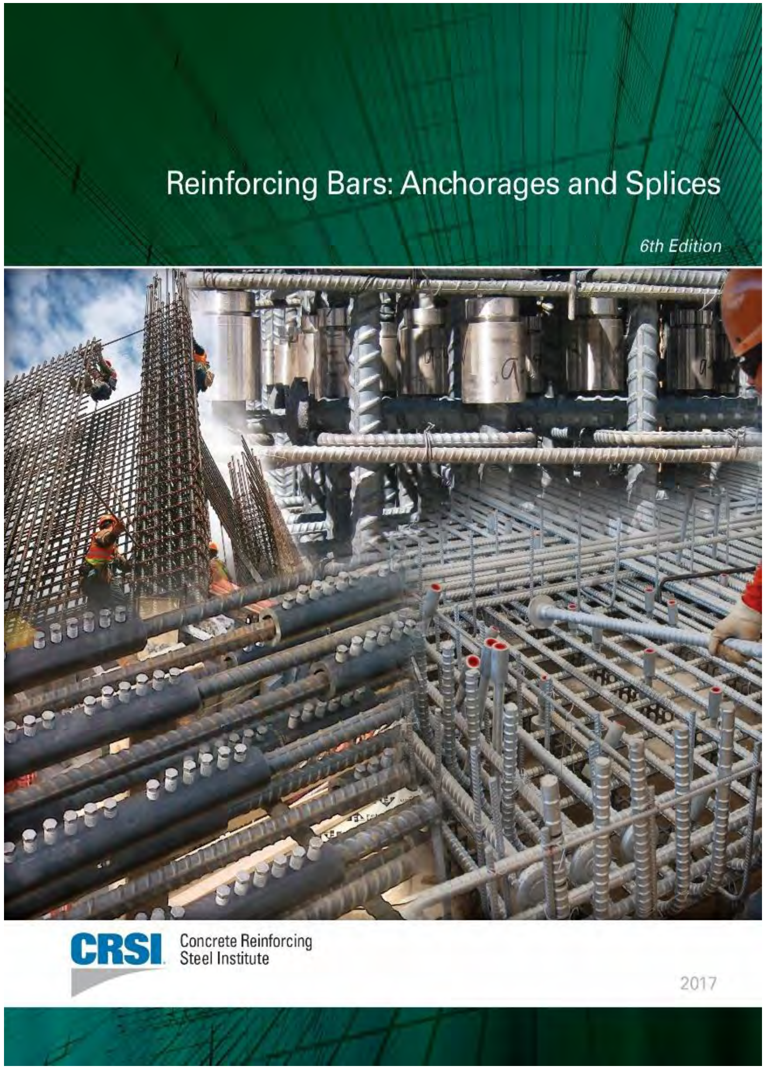
# Lap Splice vs. Coupler

- **Improved structural integrity**
  - *mechanical splices provide independent load path continuity regardless of condition of concrete*
  - *acts as one continuous piece of rebar*



# Mechanical Couplers

- **Benefits**
  - *structural integrity*
  - *continuous load path*
  - *required for the larger (#14 and above) bars*
  - *minimal cost impact*
  - *helps to reduce the congestion problems at lap splices*




**CRSI Provides several valuable Design and Reference Resources as shown here.**

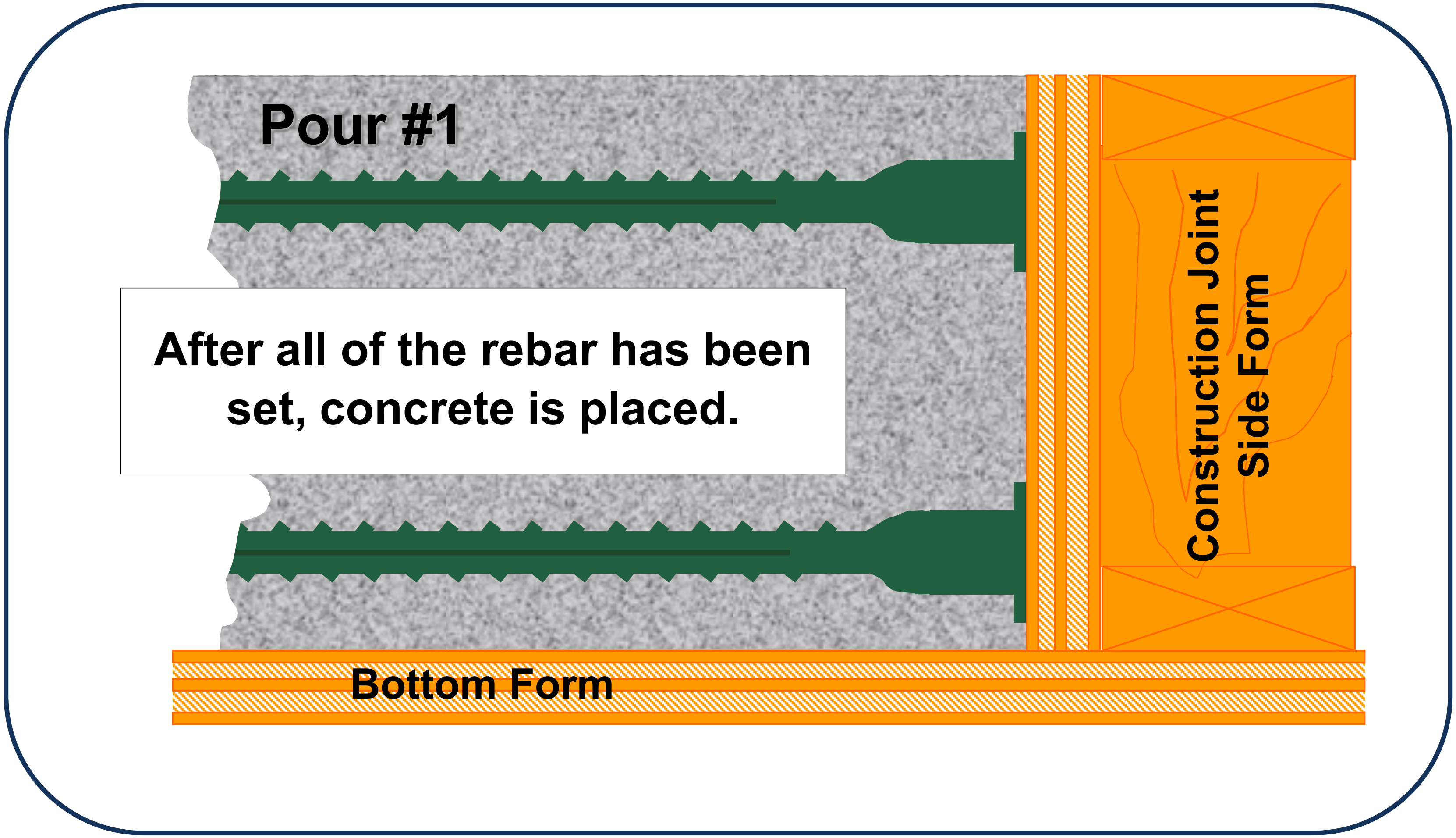
# Mechanical Couplers

- Replace lap joints
  - Large diameter bars cannot be efficiently lapped
- Facilitates consolidation of concrete
- Tension – Compression
- Compression only
- Type 1, 125% of yield
- Type 2, 100% of tensile or ultimate

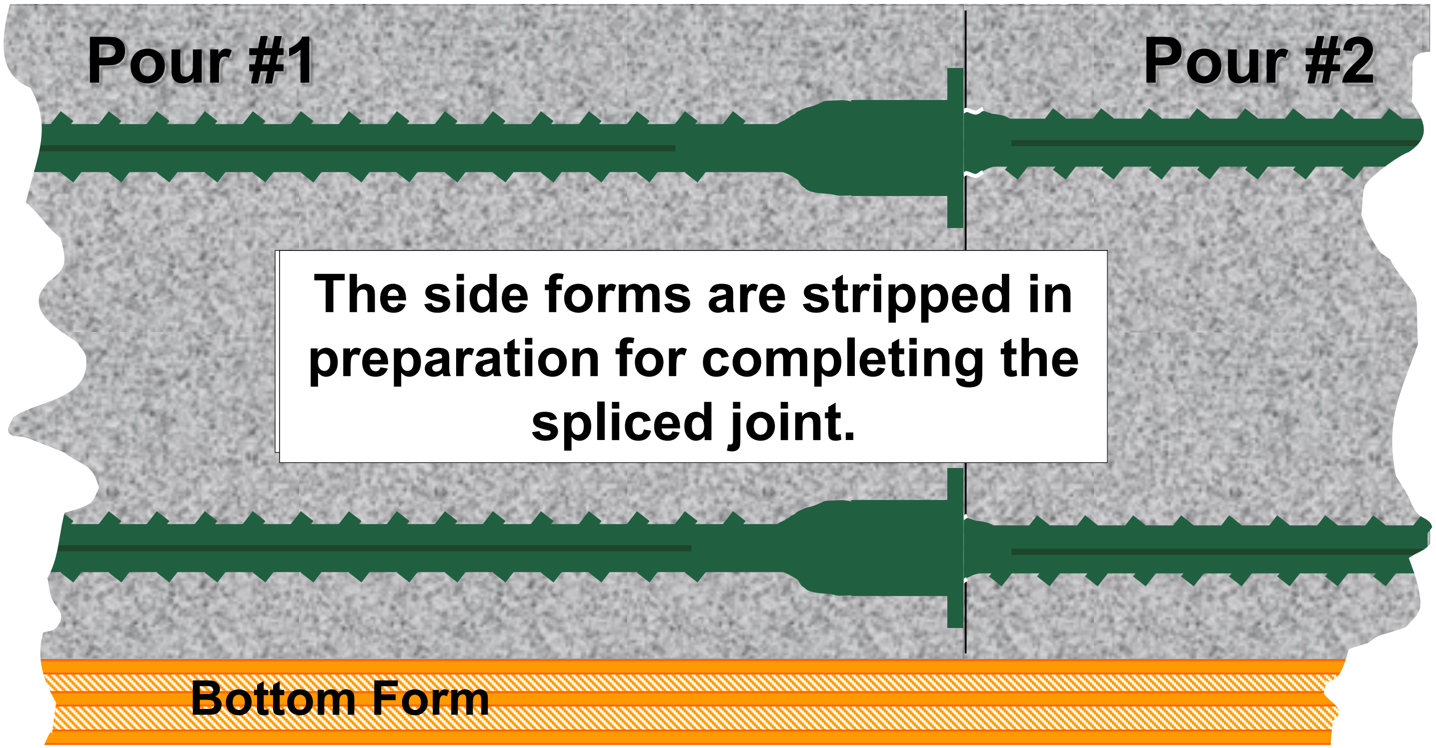
# Which Coupler is Best?

- **ASTM A1034, *Test Methods for Testing Mechanical Splices for Steel Reinforcing Bars***
  - *Test methods contained in ASTM A1034 are applicable to any type of mechanical splice manufactured to join steel reinforcing bars of any strength level (grade of steel).*

# Extenders (Form Savers)



# Extenders (Form Savers)



# Grade 60 vs. High-Strength


**Cary Kopczynski and Company**

# Resources

CRSI produces Tech Notes on high strength steel covering :

- Design
- Detailing
- Fabrication
- Placing

ENGINEERING
ETN-M-8-16

Technical Note

# High-Strength Reinforcing Bars

## Introduction

Grade 60 reinforcing steel, with a yield strength of 60,000 psi, is the most commonly used Grade in North America. Recent advances have enabled reinforcing steels of higher strengths to be commercially produced.

In ATC 115 (ATC 2014), high-strength reinforcing bars (HSRB) were considered any reinforcing bar with a yield strength greater than 60,000 psi. This Technical Note presents pertinent information on the following topics related to HSRB:

- Material properties
- ACI 318 requirements and limitations
- Main benefits
- Issues related to design and detailing of reinforced concrete members
- Availability

ACI 318 is periodically updated to include requirements for higher strength reinforcing bars as new reinforcing steel products appear in the marketplace. The following is a brief history of the appearance and adoption of the various Grades of reinforcing bars in ASTM specifications and ACI 318:

- Grades 33, 40, and 50 were in common use from the early 1900s through the early 1960s.
- Grades 60 and 75 reinforcing bars appeared in 1959 with publication of ASTM A432 (ASTM 1959a) and ASTM A431 (ASTM 1959b), respectively.
- The 1963 edition of ACI 318 allowed the use of reinforcing bars with a yield strength of 60,000 psi.
- In 1968, ASTM A615 first appeared, which included Grades 40, 60, and 75 deformed reinforcing bars.
- Grade 75 bars appeared in the 2001 edition of ASTM 955, and Grade 100 bars appeared in the inaugural 2004 edition of ASTM 1035[1]. The 2007 editions of these specifications first appeared in ACI 318-08, with ASTM 1035 containing requirements for both Grade 100 and Grade 120 bars.
- A yield strength of 100,000 psi was permitted for confinement reinforcement in the 2005 edition of ACI 318 for use in non-seismic applications and then in the 2008 edition of ACI 318 for use in seismic applications.
- The 2009 editions of ASTM A615 and ASTM A706 were the first to include requirements for Grade 80 reinforcing bars, which were adopted into the 2011 edition of ACI 318.

Tables 20.2.2.4a and 20.2.2.4b of the 2014 edition of ACI 318 (ACI 2014) contain the latest requirements and limitations for nonprestressed deformed reinforcement and nonprestressed plain spiral reinforcement, respectively. This document focuses on ASTM A615 and A706 reinforcing bars.

Currently available reinforcing bar grades, minimum yield strengths, and minimum tensile strengths are given in Table 1. The information in the table is taken from the respective ASTM specifications.

ASTM A706 requires that the actual tensile strength $f_u$ shall not be less than 1.25 times the actual yield strength $f_y$ (ASTM 2016b). Additional information on this requirement is given below. The other types of reinforcing steel are not subject to any similar requirement. ASTM A706 is also currently available only up to Grade 80 primarily due to the chemical composition restrictions in that specification related to weldability without preheating.

[1] Disclaimer: This CRSI document contains requirements that can, at the time of the document's adoption by CRSI, be satisfied only by use of a patented material, product, process, procedure, or technology. During the document preparation, the committee and Engineering Practice Committee (EPC) were informed in writing that the document under consideration involves the potential use of patented technology. The specific patented products being referenced include the following: reinforcing steel bar produced to ASTM A1035/A1035M and certain stainless steel alloys listed in Table 1 of ASTM A276.

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# Resources

CRSI new Tech Notes on high strength steel covering :

- A615 Grade 80
- A615 grade 100

- Free to download at CRSI.org (resource materials)

ENGINEERING
ETN-D-7-20
Technical Note

## Guide to the Use of Grade 80 Reinforcing Bars in ACI 318-19

### Introduction

Grade 60 reinforcing steel, with a yield strength of 60,000 psi, is the most commonly used grade in North America. Recent advances, including substantial new research, have enabled reinforcing steels of higher strengths to be a viable option in a variety of applications in reinforced concrete structures.

Permissible applications of high-strength steel reinforcement (that is, reinforcement with a yield strength of 80,000 or 100,000 psi) were significantly expanded in the 2019 edition of *Building Code Requirements for Structural Concrete and Commentary* (ACI 2019). The purpose of this Technical Note is to summarize the requirements in ACI 318-19 related to Grade 80 reinforcing bars. Industry professionals should find the information useful when designing, detailing, and specifying Grade 80 reinforcing bars in building projects. Benefits related to the use of Grade 80 reinforcing bars are also included.

Information on the design and detailing of cast-in-place reinforced concrete buildings with high-strength steel reinforcement, including worked-out design examples, can be found in *Design Guide on the ACI 318 Building Code Requirements for Structural Concrete – ACI 318-19* (CRSI 2020).

### Types of Nonprestressed Grade 80 Reinforcing Bars

Grade 80 deformed reinforcing bars must conform to the following specifications (ACI 20.2.1.3):[1]

- ASTM A615 (ASTM 2018a) – carbon steel, including the requirements in ACI Table 20.2.1.3(a)
- ASTM A706 (ASTM 2016a) – low-alloy steel, including the requirements in ACI 20.2.1.3(c)
- ASTM A955 (ASTM 2018b) – stainless steel

Similarly, Grade 80 plain reinforcing bars for spiral reinforcement must conform to the following specifications (ACI 20.2.1.4):

- ASTM A615 (ASTM 2018a)
- ASTM A706 (ASTM 2016a)
- ASTM A955 (ASTM 2018b)

Bar sizes larger than #18 are given in current editions of ASTM A615 and ASTM A1035. Due to the lack of information on their performance (including bar bends and the determination of development lengths), bar sizes larger than #18 are not permitted by ACI 318-19 (ACI R20.2.1.3).

New property requirements are given in ACI Table 20.2.1.3(a) for ASTM A615 Grade 80 deformed reinforcing bars and in ACI Table 20.2.1.3(c) for ASTM A706 Grade 80 deformed reinforcing bars (see Tables 1 and 2, respectively). These requirements are not included in the 2018 edition of ASTM A615 and the 2016 edition of ASTM A706, which are the referenced specifications in ACI 318-19 (see ACI 3.2.4).[2]

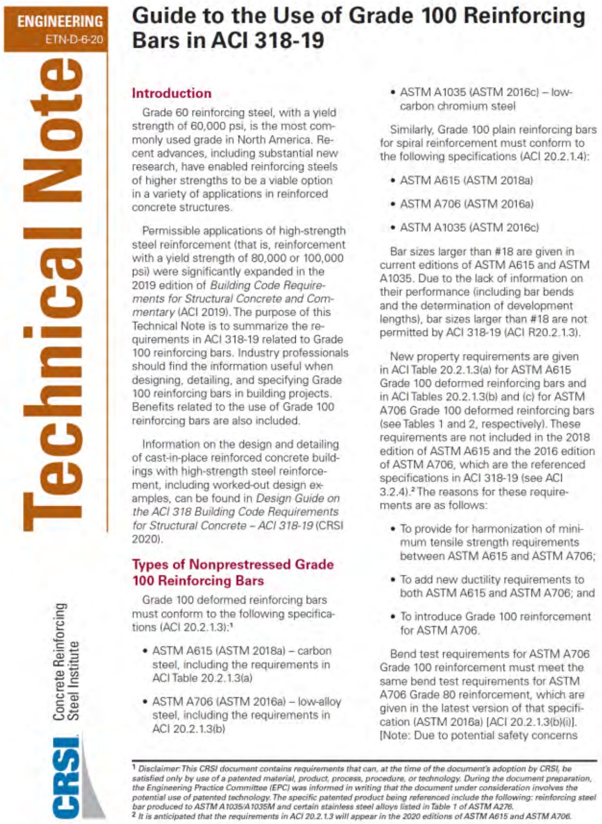
Bend test requirements for ASTM A706 Grade 80 reinforcement are given in the latest version of that specification (ASTM 2016a). [Note: Due to potential safety concerns with shop fabrication, CRSI does not recommend bending reinforcing bars larger than #14 with a grade designation of Grade 75 or higher.]

The following new requirement was introduced for all grades of ASTM A706 deformed reinforcing bars (ACI 20.2.1.3(b)(iii)): The radius on newly-machined rolls used to manufacture reinforcing bars must be at least 1.5 times the height of the deformation, h (see Figure 1). This requirement applies to all deformations, including transverse lugs, longitudinal ribs, grade ribs, grade marks, and intersections between deformations. Conformation is assessed by measurements taken on newly-machined rolls used to manufacture

[1] *Disclaimer: This CRSI document contains requirements that can, at the time of the document's adoption by CRSI, be satisfied only by use of a patented material, product, process, procedure, or technology. During the document preparation, the Engineering Practice Committee (EPC) was informed in writing that the document under consideration involves the potential use of patented technology. The specific patented product being referenced include certain stainless steel alloys listed in Table 1 of ASTM A276.*

[2] *It is anticipated that the requirements in ACI 20.2.1.3 will appear in the 2020 editions of ASTM A615 and ASTM A706.*

CRSI Concrete Reinforcing Steel Institute



ENGINEERING
ETN-D-6-20
Technical Note

## Guide to the Use of Grade 100 Reinforcing Bars in ACI 318-19

### Introduction

Grade 60 reinforcing steel, with a yield strength of 60,000 psi, is the most commonly used grade in North America. Recent advances, including substantial new research, have enabled reinforcing steels of higher strengths to be a viable option in a variety of applications in reinforced concrete structures.

Permissible applications of high-strength steel reinforcement (that is, reinforcement with a yield strength of 80,000 or 100,000 psi) were significantly expanded in the 2019 edition of *Building Code Requirements for Structural Concrete and Commentary* (ACI 2019). The purpose of this Technical Note is to summarize the requirements in ACI 318-19 related to Grade 100 reinforcing bars. Industry professionals should find the information useful when designing, detailing, and specifying Grade 100 reinforcing bars in building projects. Benefits related to the use of Grade 100 reinforcing bars are also included.

Information on the design and detailing of cast-in-place reinforced concrete buildings with high-strength steel reinforcement, including worked-out design examples, can be found in *Design Guide on the ACI 318 Building Code Requirements for Structural Concrete – ACI 318-19* (CRSI 2020).

### Types of Nonprestressed Grade 100 Reinforcing Bars

Grade 100 deformed reinforcing bars must conform to the following specifications (ACI 20.2.1.3):[1]

- ASTM A615 (ASTM 2018a) – carbon steel, including the requirements in ACI Table 20.2.1.3(a)
- ASTM A706 (ASTM 2016a) – low-alloy steel, including the requirements in ACI 20.2.1.3(b)
- ASTM A1035 (ASTM 2016c) – low-carbon chromium steel

Similarly, Grade 100 plain reinforcing bars for spiral reinforcement must conform to the following specifications (ACI 20.2.1.4):

- ASTM A615 (ASTM 2018a)
- ASTM A706 (ASTM 2016a)
- ASTM A1035 (ASTM 2016c)

Bar sizes larger than #18 are given in current editions of ASTM A615 and ASTM A1035. Due to the lack of information on their performance (including bar bends and the determination of development lengths), bar sizes larger than #18 are not permitted by ACI 318-19 (ACI R20.2.1.3).

New property requirements are given in ACI Table 20.2.1.3(a) for ASTM A615 Grade 100 deformed reinforcing bars and in ACI Tables 20.2.1.3(b) and (c) for ASTM A706 Grade 100 deformed reinforcing bars (see Tables 1 and 2, respectively). These requirements are not included in the 2018 edition of ASTM A615 and the 2016 edition of ASTM A706, which are the referenced specifications in ACI 318-19 (see ACI 3.2.4).[2] The reasons for these requirements are as follows:

- To provide for harmonization of minimum tensile strength requirements between ASTM A615 and ASTM A706;
- To add new ductility requirements to both ASTM A615 and ASTM A706; and
- To introduce Grade 100 reinforcement for ASTM A706.

Bend test requirements for ASTM A706 Grade 100 reinforcement must meet the same bend test requirements for ASTM A706 Grade 80 reinforcement, which are given in the latest version of that specification (ASTM 2016a) [ACI 20.2.1.3(b)(i)]. [Note: Due to potential safety concerns

[1] *Disclaimer: This CRSI document contains requirements that can, at the time of the document's adoption by CRSI, be satisfied only by use of a patented material, product, process, procedure, or technology. During the document preparation, the Engineering Practice Committee (EPC) was informed in writing that the document under consideration involves the potential use of patented technology. The specific patented product being referenced include the following: reinforcing steel bar produced to ASTM A1035/A1035M and certain stainless steel alloys listed in Table 1 of ASTM A276.*

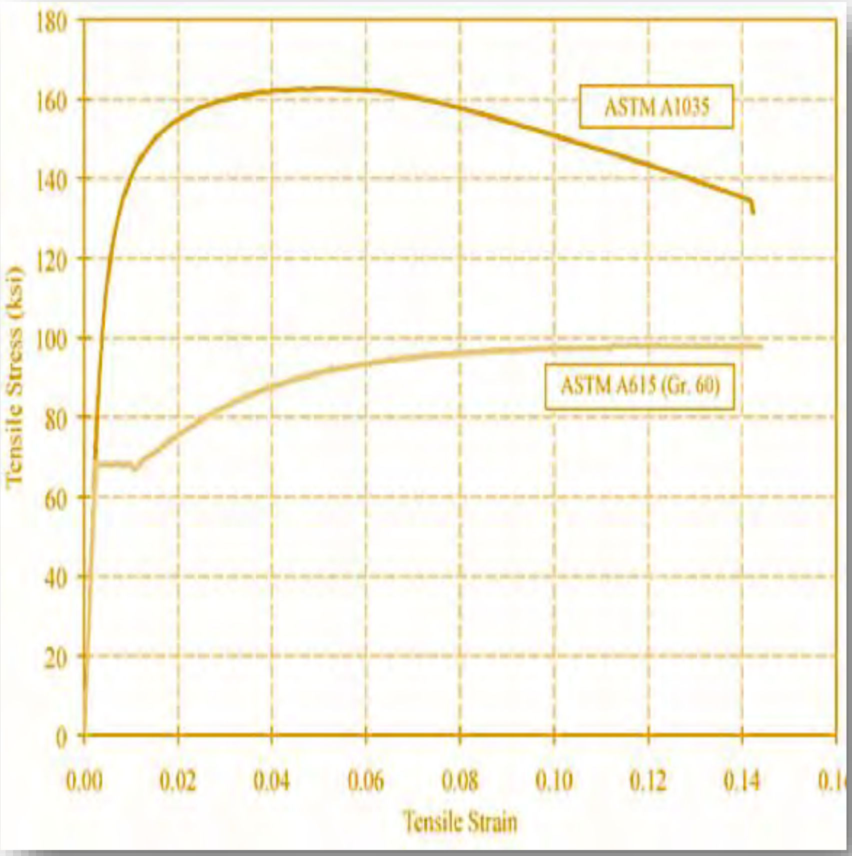
[2] *It is anticipated that the requirements in ACI 20.2.1.3 will appear in the 2020 editions of ASTM A615 and ASTM A706.*

CRSI Concrete Reinforcing Steel Institute

CRSI Concrete Reinforcing Steel Institute

# High-Strength Steel Design

- Grade 100 is not simply Grade 60 on steroids!
- Lack of a well defined yield plateau versus Grade 60 affects flexural behavior of beams significantly.



# High-Strength Reinforcement
## (above 60 ksi yield)

**Positives**

Reduces congestion

» less bars needed
» increases bar spacing
» reduces bar diameter

Faster construction

» placing / tying bars (labor)
» less weight ~ cranes

Concrete placement ease

# High-Strength Reinforcement Considerations

**Negatives**

Slower fabrication / production

- shearing rates lower

Distribution / delivery

Jobsite inventory control

- markings
- storage

Applicable specifications?

# Metallurgical Properties of Ultra-High-Strength Steel

## (90 ksi or higher yield strength)

How is ultra-high-strength steel achieved?

- quenching and tempering
    - quenches surface layer and pressurizes intermediate layers
- thermo-mechanical treatment (TMT)
    - strain hardening/cold work and heat treatment
- addition of vanadium (expensive)

# High-Strength Steel Resources



- ACI ITG-6
  (*ASTM A-1035)*
- NCHRP 679
  *TRB document*

# Welding

# Field Bending

# ACI and In-Situ Bending

## BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE (ACI 318-14)

**26.6.3** *Bending*

**26.6.3.1** Compliance requirements:

**(a)** Reinforcement shall be bent cold prior to placement, unless otherwise permitted by the licensed design professional.

**(b)** Field bending of reinforcement partially embedded in concrete shall not be permitted, except as shown in the construction documents or permitted by the licensed design professional.

**(c)** Offset bars shall be bent before placement in the forms.

# CRSI and In-Situ Bending

## Field Corrections to Rebars Partially Embedded in Concrete – CRSI Engineering Data Report #12

Studied cold versus hot bending; effects of the type, degree and axis of bend; effect of bar size and deformation pattern; effect of cold-temperature bending; and the differences between accidental and deliberate bending.

- Reworking of bars partially embedded in concrete entails some risk.
- Bars of #8 or smaller size can be successfully field bent or straightened at temperatures above about 32° F.
- Bar sizes #9, #10 and #11 have a better chance of being successfully bent or straightened if the bend area is uniformly preheated to 1400 to 1500° F and extreme care is exercised in the bending or straightening operation.
- The applicability of these conclusions to size #14 to #20 bars is uncertain.

# Concluding Remarks

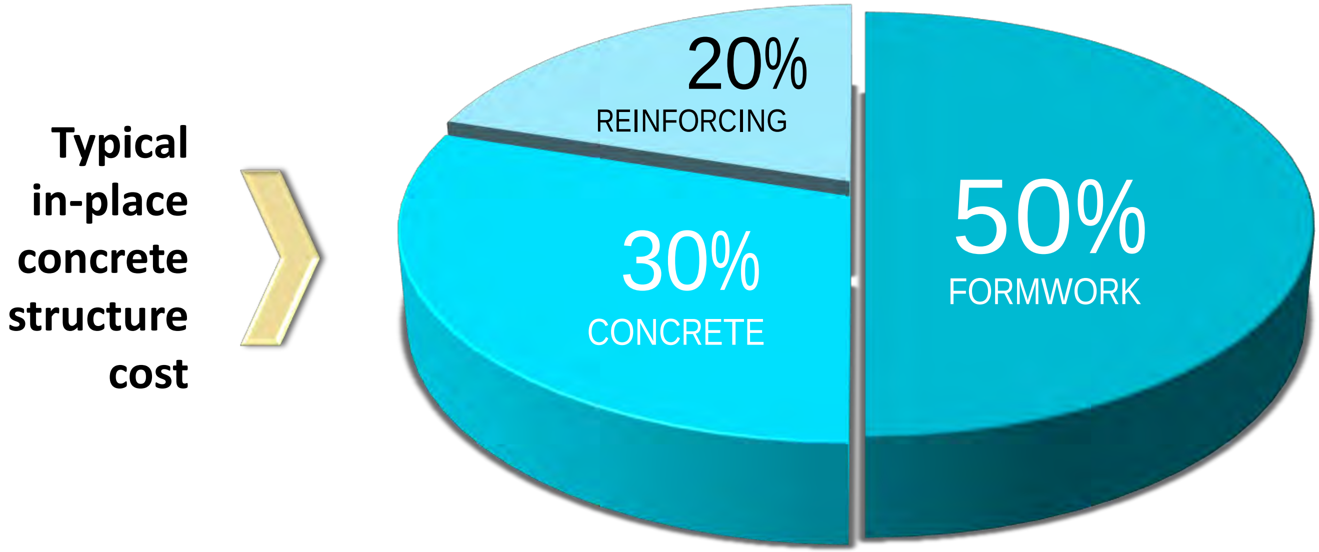
- Wide choice of materials
  - » *combinations are often better*
- Understand the material
  - » *any material can be misused or misapplied*
  - » *improper handling on ANY MATERIAL may reduce its performance*
- Overall performance is not the only criteria
  - » *sustainability*
  - » *initial and life-cycle cost*
  - » *availability*

# Introducing CRSI Explorer – CRSI.org


- Explore ways in which concrete structural systems can contribute to project objectives.
- Use as an early team collaboration tool.
- Early exploration can frequently reveal project-specific opportunities.

# Cost of Concrete Construction

The cost of concrete construction and repair can be reduced, sometimes dramatically, by following a few simple rules in the preliminary layout and design of the structure.



# Introducing Reinforced Concrete Concept CRSI.org


- Evaluate and compare common concrete floor systems.
- Estimates rely on cost factors you select and trust.
- Available free and on-demand from the CRSI website.
- Evaluations are fast and interactive.

# Summary

- CRSI has numerous resources to assist you online or in person
- Contact a CRSI Regional manager in your area

Pdye@crsi.org

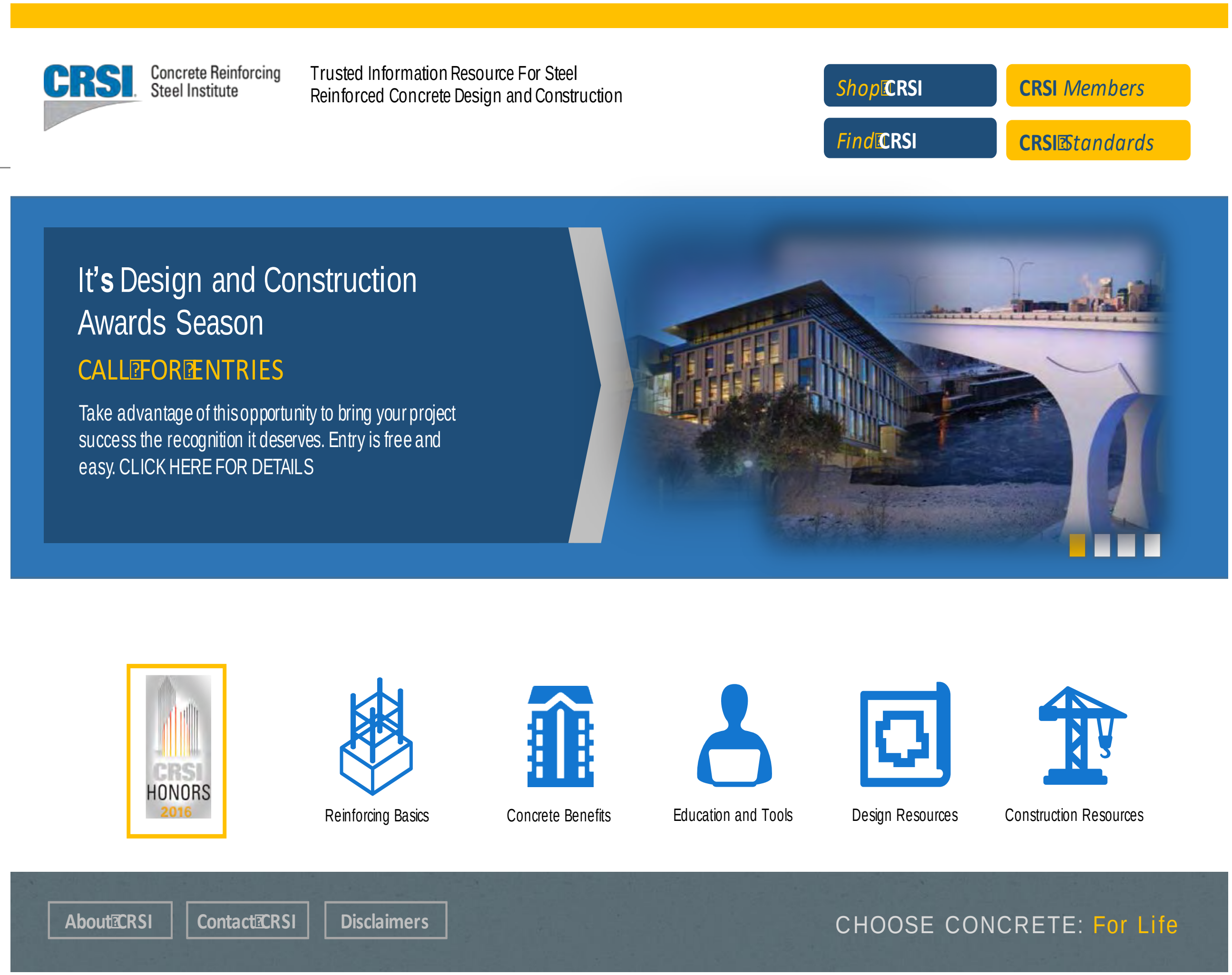
https://www.crsi.org/

https://learning.crsi.org/

## Current Presentation Offerings

- DG on ACI 318-19 Introduction
- Architectural Concrete
- Reinforced Concrete Floor Systems
- Emerging Trends
- Field Inspection of Reinforcing
- Forming Framing Innovations
- Health Care Facility Benefits for the Designer & Owner
- Multifamily Benefits for the Designer & Owner
- Reinforcing Steel Options

# Look to CRSI for answers to your reinforced concrete questions at www.crsi.org



# Conclusion

- questions