Questions and Answers on ASTM A 706 Reinforcing Bars

by David P. Gustafson and Anthony L. Felder

The types of reinforcing bars used in the United States are billet-steel, rail-steel, axle-steel, and low-alloy steel. Billet-steel bars conforming to the ASTM A 615[1] specification are the most widely used type. Low-alloy steel bars conforming to the ASTM A 706[2] specification are the most recent type.

Questions are frequently raised by architect-engineers and constructors regarding A 706 reinforcing bars. Their questions typically are concerned with a wide range of practical items such as mechanical properties, weldability, availability, and relative costs.

This article, in question-and-answer format, has resulted essentially from the dialogue with many architect-engineers and constructors and is based on a Concrete Reinforcing Steel Institute CRSI engineering data report. In it, the major requirements in the ASTM A 706 specification are discussed, and information on the use and availability of low-alloy reinforcing bars is presented.

Development of specification

When was the ASTM A 706 specification issued and why was the specification prepared and adopted as an ASTM standard?

The first edition of the specification was adopted in 1974. The report by ACI Committee 439[3] includes an interesting description of its background and development.

The Structural Engineers Association of California (SEAOC) was influential in getting ASTM to prepare and issue the A 706 specification. In seismic design, it is essential for the reinforcing steel to have controlled tensile properties. SEAOC wanted a reinforcing bar specification that would have the necessary controls on tensile properties and would also include requirements to enhance ductility and bendability. To facilitate construction, SEAOC also wanted the specification to provide for weldable bars.

Are there any other points regarding the background or development of the specification that ought to be mentioned?

From an historical perspective, perhaps it should be mentioned that during the period when SEAOC was pressing for a new specification, there was also considerable activity in nuclear power plant construction in the U.S. The Joint ACI-ASCE Committee 359 on Concrete Components for Nuclear Reactors also had an interest in developing the new specification.

It should also be noted that a major producer of reinforcing bars at that time (in the 1960s) made a proprietary deformed bar that had essentially the desired mechanical properties and requirements for weldability. That producer provided considerable input to the A 706 specification.

Mechanical properties

What are the main requirements for tensile properties in the A 706 specification?

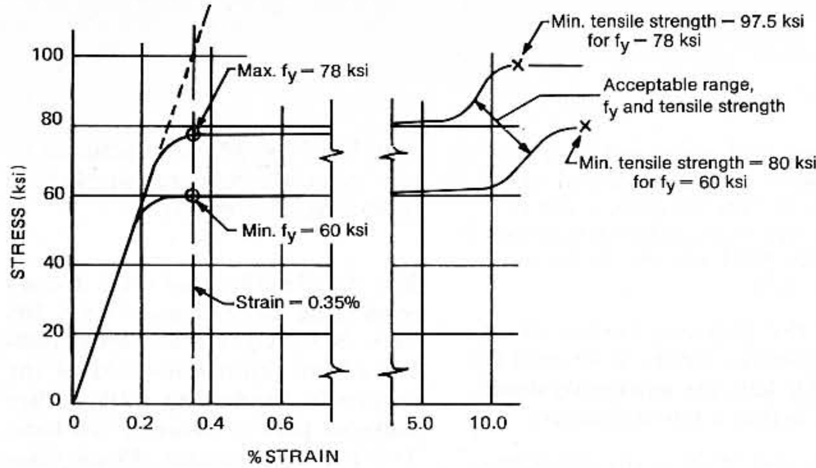
The specification covers only one strength level of bars, that is, Grade 60; hence, the specification prescribes a minimum yield strength of 60,000 psi (415 MPa). The prescribed minimum tensile strength is 80,000 psi (550 MPa). There are also two other limits, or controls, on tensile strength properties: the yield strength cannot exceed 78,000 psi (540 MPa), and the tensile strength cannot be less than 1.25 times the actual yield strength.

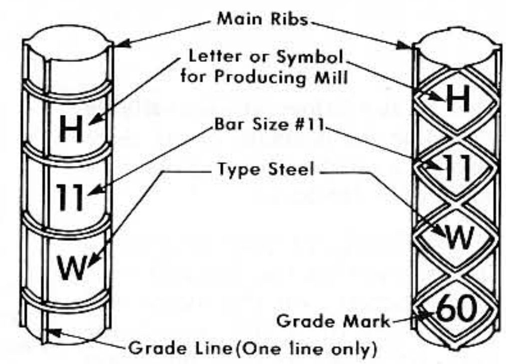
The latter requirement, a minimum tensile-yield ratio, will control when the actual yield strength of a bar is greater than 64,000 psi (440 MPa), the yield strength obtained in a laboratory tensile test. In other words, if bars were tensile-tested in a laboratory and the measured yield strengths ranged from 64,000 to 78,000 psi (440 to 540 MPa), the corresponding tensile strengths would have to range from at least 80,000 to 97,500 psi (550 to 670 MPa). As an example, if the laboratory-measured value of yield strength was 68,000 psi (470 MPa), the measured tensile strength would have to be at least 1.25 x 68,000, or 85,000 psi (585 MPa), to conform to the specification.

What other tensile properties are prescribed in A 706?

Percentage of elongation; the A 706 specification requires larger values of minimum percentage of elongation as compared to the values prescribed in the other specifications for reinforcing bars.

What other mechanical properties are prescribed in the specification?





(left) Fig. 1 — Stress-strain curves for A 706 reinforcing bars. (right) Fig. 2 — Required marking for A 706 reinforcing bars.

They are similar to the other reinforcing bar specifications, although the A 706 bend test requirements are more restrictive (smaller bend test pin diameters) than those in the other specifications. See Reinforcing Bar Testing[4] for the bend test pin diameter requirements in the reinforcing bar specifications.

What is the significance of the prescribed, or controlled, tensile properties?

The specification is, in effect, prescribing tailored stress-strain curves for the bars (Fig. 1). In designing seismic-resistant reinforced concrete structures, the tensile properties of the reinforcing bars should be controlled within desired limits, and the bars should have a definite yield plateau and a definite strain-hardening region.

The lower stress-strain curve in Fig. 1 corresponds to the minimum requirements in A 706, namely, minimum yield strength f_y = 60 ksi (415 MPa), and minimum tensile strength = 80 ksi (550 MPa). The upper stress-strain curve is the upper limit for tensile properties; maximum f_y = 78 ksi (540 MPa), and tensile strength at least = 1.25 × 78 = 97.5 ksi (670 MPa).

Weldability

The other major requirement in the A 706 specification concerns weldability. How does the specification provide for weldable bars?

Unlike the other ASTM specifications for reinforcing bars, A 706 includes the statement: "This material is intended for welding." Weldability is accomplished by limits, or controls, on chemical composition. There are actually two limits on chemical composition. One is on individual chemical elements; the other is on "carbon equivalent."

Table 1 — Minimum preheat and interpass temperatures, F

C.E. range, percent	Bar sizes #3 - #6	#7 - #11	#14 - #18
0.40 maximum	0	0	50
0.41 to 0.45	0	0	100
0.46 to 0.55	0	50	200
0.56 to 0.65	100	200	300
0.66 to 0.75	300	400	400
Above 0.75	500	500	500

What is "carbon equivalent?"

The term, which is abbreviated as C.E., accounts for those chemical elements affecting weldability, and is a numerical value expressed as a percent. The ANSI/AWS D1.4-79[5] and the ASTM A 706 reinforcing bar specification have the same formula for C.E.

$$\text{C.E.} = \%\text{C} + \frac{\%\text{Mn}}{6} + \frac{\%\text{Cu}}{40} + \frac{\%\text{Ni}}{20} + \frac{\%\text{Cr}}{10} - \frac{\%\text{Mo}}{50} - \frac{\%\text{V}}{10}$$

What are the limits on individual chemical elements and carbon equivalent in the A 706 specification?

The limits on the major chemical elements affecting weldability (elements in the C.E. formula) are maximum percentages of 0.30 carbon and 1.50 manganese. The carbon equivalent is limited to 0.55 percent. Note also that the A 706 specification requires the producer to report the chemical composition and carbon equivalent to the purchaser.

How do those limits tie into weldability and the ANSI/AWS Welding Code?

The minimum preheat and interpass temperatures in the ANSI/AWS Welding Code are based upon carbon equivalent and reinforcing bar size. For bars with a carbon equivalent up to 0.55 percent, little or no preheat is required under normal working temperatures for bar sizes #11 and smaller. For #14 and #18 bars with a carbon equivalent of 0.40 to 0.55 percent, a somewhat higher preheat is required (Table 1). In many cases, when a small quantity of weldable reinforcing bars is required for a project, it can be more economical to specify A 615 bars and weld according to the more stringent requirements prescribed in ANSI/AWS D1.4-79.

Usage

It was noted in the answer to the first question that the A 706 specification was issued over 15 years

ago. Is any information available regarding the demand, or are there any data on the past and current usage of A 706 bars?

It is difficult to report meaningful information on the demand and, consequently, on the usage and availability of A 706 reinforcing bars. Hard data on these important aspects are sparse.

Please elaborate on usage.

Perhaps it is best to begin to describe usage by relating to current practices in the marketplace.

First, consider cast-in-place concrete construction. At the time the specification was issued, the nuclear power industry was in the process of contracting for its plant construction. Since then, there have been no orders for plants. On the West Coast, where the campaign for the A 706 specification began, structural engineers often specify reinforcing bars for seismic-resistant structures as:

> The reinforcing bars shall conform to ASTM A 706-XX; or to ASTM A 615-XX, Grade 60, except (1) the maximum yield strength shall be 78,000 psi, and (2) the tensile strength shall not be less than 1.25 times the actual yield strength.

In other words, practicing structural engineers permit the use of ASTM A 615, Grade 60 bars having special, or tailored, stress-strain curves (Fig. 1) — the controlled tensile properties desired for optimum structural performance under seismic loading.

Permitting the use of modified A 615 Grade 60 bars by structural engineers is not surprising. Chapter 21 in the ACI Building Code[6] also permits the same option:

> **21.2.5.1** — Reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary members shall comply with ASTM A 706. ASTM A 615 Grades 40 and 60 reinforcement are allowed in these members if (a) the actual yield strength based on mill tests does not exceed the specified yield strength by more than 18,000 psi (retests shall not exceed this value by more than an additional 3000 psi); and (b) the ratio of the actual tensile strength to the actual tensile yield strength is not less than 1.25.

From the previous answer, it appears that the emphasis or need for weldable bars has apparently diminished. Is that a fair statement?

Yes, it appears that the anticipated demand for weldable bars in cast-in-place construction never fully materialized.

Is there any basis for the diminishing interest or need for weldable reinforcing bars?

Perhaps it is due to the increased use of proprietary mechanical connections for butt splicing reinforcing bars in cast-in-place construction. In most areas of the country, including seismic regions, mechanical connections seem to be preferred for butt splicing, particularly for the larger size bars.

The answers have focused on cast-in-place construction. Why?

It was necessary to differentiate, or single out, cast-in-place construction because there is some use, generally of the smaller bar sizes, in the precast concrete industry.

Any other comments on usage?

A 706 bars in the smaller sizes, like A 615 bars, can be furnished in coils. Coiled stock is preferred by some reinforcing bar fabricators for use with their automatic stirrup and tie bending machines. While use of coiled stock provides for efficient and cost-effective fabricating practices, and the use is growing, total tonnage is rather small.

Coiled stock, mainly A 615 bars rather than A 706 material, is also used by manufacturers of reinforced concrete pipe.

Availability

What about the availability of A 706 bars?

A recent survey conducted by CRSI of the 35 known manufacturers of reinforcing bars in the U.S. showed that 13 of the 35 manufacturers either currently produce, or plan on producing, A 706 bars.

You stated earlier that there doesn't seem to be much demand for A 706 bars. But the previous answer indicates that about one-third of the currently producing mills either make or plan to make A 706 bars. This is a bit confusing. Please elaborate.

The key words are "currently produce" or "plan on producing," and perhaps the latter should also include "capable of producing." Several producers have made and currently produce A 706 bars. Several others are interested and capable of producing the bars. Two facets should be considered: demand in the marketplace and economics.

First, the demand for A 706 bars has never materialized, per se. As mentioned earlier, structural engineers specify and the building codes permit use of A 615 bars with the special tensile properties of A 706. The use of weldable bars has diminished.

Regarding economics, reinforcing bar producers make steel in units called "heats," which, depending on the mill, may range in size from 30 to 200 tons (25 to 180 Mg). Bars produced to meet the A 706 specification have to be marked with a "W" for the type of steel (Fig. 2). For orders of smaller quantities, it might be prohibitive, costwise, for producers to dress their rolls to accommodate the "W" mark. To make it economically feasible for a producer to make the bars with the "W" mark, an order should comprise at least 200 to 400 tons (180 to 365 Mg) for one pass of the rolls. Smaller quantities may be available if the "W" marking requirement is waived.

Can more specific cost information be stated?

For the purpose of the discussion here, and for cost estimating, using Reference 7 as a basis, if the cost of a relatively large order of A 615 reinforcing bars at a mill is $300 a ton, the cost of a comparable quantity of A 706 bars might be 6 to 10 percent higher, say $320 to $330 a ton.

Production costs were addressed in the answer to the previous questions. Are there other possible increased costs for A 706 bars?

Yes. Fabricators of reinforcing bars might be reluctant to carry and maintain another inventory of bars because it would probably add to their cost of doing business. In addition, reinforcing bar producers generally do not maintain a large inventory of A 706 bars, and those inventories that are maintained are often limited to 40-ft. (12-m) lengths. This limit on inventory would affect the availability of A 706 bars for a particular project.

For smaller jobs, it could be like a Catch-22 situation; a fabricator may experience difficulty in getting small quantities of A 706 bars from a producer, and a contractor may not be able to find a supplier who can furnish the fabricated bars for the job. For large projects with adequate lead time, the problems in procuring A 706 bars should be minimal.

Any further comments on relative costs?

No track record has been established regarding the demand, usage, and availability of A 706 reinforcing bars, so realistic costs are elusive. An architect-engineer should be cautious in assigning costs to A 706 bars in preliminary designs and cost estimates, and especially in cost estimates used in comparisons with competitive structural materials and systems.

Another question about current usage: how many tons or what percentage of the total tonnage is A 706?

The American Iron and Steel Institute (AISI) collects and disseminates data on production and usage, i.e., shipments of all steel products in the U.S. Regarding reinforcing bars, 5,387,000 tons (4,887,000 Mg) were shipped in 1990. The reports by AISI do not break down the reinforcing bar shipments by type of steel.

Recently, CRSI conducted another survey of all known reinforcing bar producers in the U.S., including the type and grade of steel they produced in 1990. Not all producers responded to the survey. Responses regarding the type of steel represented about 4 million tons (3.6 million Mg), and less than one percent of the surveyed total was A 706.

Any closing comments?

To summarize:

- If the reinforcing bars for a project do not require controlled tensile properties and/or weldability, specify other types of bars.
- Before completing a design or specifying A 706 bars, the prudent designer should investigate local availability.
- For use in seismic-resistant structures where welded splices are not going to be used, consider specifying A 615 bars with additional requirements for tensile properties. For butt splicing A 615 bars, consider using mechanical connections.

References

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4. *Reinforcing Bar Testing,* 2nd Edition, Concrete Reinforcing Steel Institute, Schaumburg, 1989.
5. *Structural Welding Code—Reinforcing Steel (ANSI/AWS D1.4-79),* American Welding Society, Miami.*
6. ACI Committee 318, "Building Code Requirements for Reinforced Concrete (ACI 318-89/318R-89)," American Concrete Institute, Detroit, 1989, 353 pp.
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Selected for reader interest by the editors.

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*At press time, the American Welding Society was in the final stages of adopting a new edition of the D1.4 Code.