Designation: A 709/A 709M – 01a

Standard Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges[1]

This standard is issued under the fixed designation A 709/A 709M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers carbon and high-strength low-alloy steel structural shapes, plates, and bars and quenched and tempered alloy steel for structural plates intended for use in bridges. Eight grades are available in four yield strength levels as follows:

Grade U.S. [SI]	Yield Strength, ksi [MPa]
36 [250]	36 [250]
50 [345]	50 [345]
50S [345S]	50 [345]
50W [345W]	50 [345]
HPS 50W [HPS 345W]	50 [345]
HPS 70W [HPS 485W]	70 [485]
100 [690]	100 [690]
100W [690W]	100 [690]

1.1.1 Grades 36 [250], 50 [345], 50S [345S], 50W [345W], 100 [690], and 100W [690W] are also included in Specifications A 36/A 36M, A 572/A 572M, A 992/A 992M, A 588/A 588M, and A 514/A 514M, respectively. When the supplementary requirements of this specification are specified, they exceed the requirements of Specifications A 36/A 36M, A 572/A 572M, A 992/A 992M, A 588/A 588M, and A 514/A 514M.

1.1.2 Grades 50W [345W], HPS 50W [HPS 345], HPS 70W [HPS 485W], and 100W [690W] have enhanced atmospheric corrosion resistance (see 11.1.2). Product availability is shown in Table 1.

1.2 Grade HPS 70W [HPS 485W], 100 [690], or 100W [690W] shall not be substituted for Grades 36 [250], 50 [345], 50S [345S], 50W [345W], or HPS 50W [HPS 345W]. Grade 50W [345W], or HPS 50W [HPS 345W] shall not be substituted for Grades 36 [250], 50 [345] or 50S [345S] without agreement between the purchaser and the supplier.

1.3 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 Supplementary requirements are available but shall apply only when specified by the purchaser at the time of ordering.

1.5 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.6 For structural products cut from coiled product, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 6/A 6M apply.

2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 36/A 36M Specification for Carbon Structural Steel[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[2]

A 514/A 514M Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding[2]

A 572/A 572M Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel[2]

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick[2]

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel[2]

A 992/A 992M Specification for Steel for Structural Shapes for Use in Building Framing[2]

E 112 Test Methods for Determining Average Grain Size[4]

G 101 Guide for Estimating the Atmospheric Corrosion

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved September 10, 2001. Published October 2001. Originally published as A 709 – 74. Last previous edition A 709/A 709M– 01.

[2] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

TABLE 1 Tensile and Hardness Requirements[A]

NOTE 1— Where ". . ." appears in this table, there is no requirement.

Grade	Plate Thickness, in. [mm]	Structural Shapes Groups	Yield Point or Yield Strength,[B] ksi [MPa]	Tensile Strength, ksi [MPa]	Minimum Elongation, %				Reduction of Area[C,D] min, %	Brinell Hardness Number
					Plates and Bars[E,C]		Shapes[E]			
					8 in. or 200 mm	2 in. or 50 mm	8 in. or 200 mm	2 in. or 50 mm		
36 [250]	to 4 [100], incl	to 426 lb/ft (634 kg/m)	36 [250] min	58–80 [400–550]	20	23	20	21[F]	...	[G]
		over 426 lb/ft (634 kg/m)	36 [250] min	58 [400] min	...	...	20	19	...	[G]
50 [345]	to 4 [100], incl	all	50 [345] min	65 [450] min	18	21	18	21[F]	...	[G]
50S [345S]	[H]	all	50–65 [345–450][I]	65 [450][I] min	...	...	18	21	...	[G]
50W [345W] and HPS 50W [HPS 345W]	to 4 [100], incl	all	50 [345] min	70 [485] min	18	21	18	21[J]	...	[G]
HPS 70W [HPS 485 W]	to 4 [100], incl	[H]	70 [485] min[B]	85–110 [585–760]	. . .	19	. . .	. . .	. . .	[G]
100 [690] and 100W [690W]	to 2½ [65], incl	[H]	100 [690] min[B]	110–130 [760–895]	...	18[K]	...	...	40[L]–50[M]	235–293[G]
100 [690] and 100W [690 W]	over 2½ to 4 [65 to 100]	[H]	90 [620] min[B]	100–130 [690–895]	...	16[K]	...	...	40[L]–50[M]	[G]

[A] See specimen orientation and preparation subsection in the Tension Tests section of Specification A 6/A 6 M.
[B] Measured at 0.2 % offset or 0.5 % extension under load as described in Section 13 of Test Methods A 370.
[C] Elongation and reduction of area not required to be determined for floor plates.
[D] For plates wider than 24 in. [600 mm], the reduction of area requirement, where applicable, is reduced by five percentage points.
[E] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.
[F] Elongation in 2 in. or 50 mm: 19 % for shapes over 426 lb/ft [634 kg/m].
[G] Brinell requirements apply only to material ⅜ in. [10 mm] and thinner for Grades 100 and 100W.
[H] Not applicable.
[I] The yield to tensile ratio shall be 0.85 or less.
[J] For wide flange shapes over 426 lb/ft [634 kg/m], elongation in 2 in. of 18 % minimum applies.
[K] When measured on the Fig. 3 (Test Methods A 370) 1½–in. [40–mm] wide specimen the elongation is determined in a 2–in. or 50–mm gage length which includes the fracture and shows the greatest elongation.
[L] When measured on the Fig. 3 (Test Methods A 370) 1½-in. [40-mm] wide specimen.
[M] When measured on the Fig. 4 (Test Methods A 370) ½–in. [12.5–mm] round specimen.

Resistance of Low-Alloy Steels[5]

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

3.1.1 Coiled product is excluded from qualification to this specification until leveled and cut to length. Structural products produced from coil means structural products that have been cut to individual lengths from a coiled product and are furnished without heat treatment. The processor decoils, levels, cuts to length, and marks the product. The processor is responsible for performing and certifying all tests, inspections, and operations not intended to affect the properties of the material. For structural products produced from coils, two tests shall be reported for each qualifying coil. See Note 1.

NOTE 1—Additional requirements regarding structural products from coil are described in Specification A 6/A 6M.

4. Materials and Manufacture

4.1 For Grades 36 [250] and 50 [345], the steel shall be semi-killed or killed.

4.2 For Grades 50W [345W], HPS 50W [HPS 345W], and HPW 70W [485W], the steel shall be made to fine grain practice.

4.3 For Grade 50S [345S], the steel shall be killed. Killed steel is confirmed by a statement of killed steel on the test report or by reporting strong deoxidizers, such as 0.10% or more for silicon or 0.015% or more for aluminum.

4.4 For Grade 50S [345S], the steel shall be made using a practice producing nitrogen not greater than 0.012%; or the steel for Grade 50S shall be made using a practice producing nitrogen not greater than 0.015% and one or more nitrogen-binding elements shall be added.

4.5 Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W], the steel shall be made using a low-hydrogen practice, such as vacuum degassing during steel making; controlled soaking of the ingots, slabs; controlled slow cooling of the ingots, slabs, or plates, or a combination thereof.

4.6 For Grades 100 [690] and 100W [690W], the requirements for fine austenitic grain size in Specification A 6/A 6M shall be met.

4.7 Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W] shall be furnished in one of the following conditions: as-rolled, control-rolled, thermo-mechanical control processed (TMCP) with or without accelerated cooling, or quenched and tempered.

5. Heat Treatment

5.1 For quenched and tempered Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W], the heat treatment shall be performed by the manufacturer and shall consist of heating the steel to not less than 1650°F [900°C], quenching it in water or

[5] *Annual Book of ASTM Standards*, Vol 03.02.

oil, and tempering it at not less than 1100°F [590°C]. The heat-treating temperatures shall be reported on the test certificates.

5.2 For Grades 100 [690] and 100W [690W], the heat treatment shall be performed by the manufacturer and shall consist of heating the steel to not less than 1650°F [900°C], quenching it in water or oil, and tempering it at not less than 1150°F [620°C]. The heat-treating temperatures shall be reported on the test certificates.

6. Chemical Requirements

6.1 The heat analysis shall conform to the requirements for the specified grade in Tables 2-7.

6.2 For Grade 50S, in addition to the elements listed in Table 7, test reports shall include, for information, the chemical analysis for tin. Where the amount of tin is less than 0.02%, it shall be permissible for the analysis to be reported as < 0.02%.

6.3 The maximum permissible carbon equivalent value shall be 0.47% for structural shapes in Groups 4 and 5, and 0.45% for other structural shapes. The carbon equivalent shall be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported. The carbon equivalent shall be calculated using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15} \quad (1)$$

7. Tensile Requirements

7.1 The material as represented by test specimens, except as specified in 7.2, shall conform to the requirements for tensile properties prescribed in Table 1.

7.2 For Grade 36 [250] shapes less than 1 in. ^{2}[645 mm^2] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer.

8. Brinell Hardness Requirements for Grades 100 [690] and 100W [690W]

8.1 For plates ⅜in. [10 mm] and under in thickness, a Brinell hardness test may be used instead of tension testing each plate, in which case a tension test specimen shall be taken from a corner of each of two plates per lot. A lot shall consist of plates from the same heat and thickness, same prior condition and scheduled heat treatment and shall not exceed 15 tons [15 Mg] in weight. A Brinell hardness test shall be made on each plate not tension tested and shall meet the requirements shown in Table 1.

9. Test Specimens and Number of Tension Tests

9.1 For Grades 36 [250], 50 [345], and 50W [345W], and non-quenched and tempered Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W], location and condition, number of tests, and preparation of test specimens shall meet the requirements of Specification A 6/A 6M.

9.2 The following requirements, which are in addition to those of Specification A 6/A 6M, shall apply only to Grades 100 [690] and 100W [690W] and quenched and tempered Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485 W].

9.2.1 When possible, all test specimens shall be cut from the plate in its heat-treated condition. If it is necessary to prepare test specimens from separate pieces, all of these pieces shall be full thickness, and shall be similarly and simultaneously heat treated with the material. All such separate pieces shall be of such size that the prepared test specimens are free of any variation in properties due to edge effects.

9.2.2 After final heat treatment of the plates, one tension test specimen shall be taken from a corner of each plate as heat treated (except as specified in 8.1).

NOTE 2—The term "plate" identifies the "plate as heat treated."

10. Retests

10.1 Grades 36 [250], 50 [345], 50S [345S], and 50W [345W], and non-quenched and tempered HPS 50W [HPS 345W] and HPS 70W [HPS 485W] shall be retested in accordance with Specification A 6/A 6M.

10.2 Grades 100 [690] and 100W [690W] plates that are subjected to Brinell hardness tests and fail to meet the hardness requirements, at the manufacturer's option, may be subjected to tension testing and shall be accepted if the results conform to the requirements of Table 1.

10.3 The manufacturer may reheat treat quenched and tempered plates that fail to meet the mechanical property

TABLE 2 Grade 36 [250] Chemical Requirements (Heat Analysis)

NOTE 1— Where ". . ." appears in this table there is no requirement. The heat analysis for manganese shall be determined and reported as described in the Heat Analysis section of Specification A 6/A 6M.

Product Thickness, in. (mm)	Shapes[A] All	Plates[B]				Bars		
		To ¾ [20], incl	Over ¾ to 1½[20 to 40], incl	Over 1½ to 2½[40 to 65], incl	Over 2½to 4 [65 to 100], incl	To ¾ [20], incl	Over ¾ to 1½ [20 to 40], incl	Over 1½to 4 [100], incl
Carbon, max, %	0.26	0.25	0.25	0.26	0.27	0.26	0.27	0.28
Manganese, %	...	...	0.80–1.20	0.80–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90
Phosphorus, max, %	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max, %	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, %	0.40 max	0.40 max	0.40 max	0.15–0.40	0.015–0.40	0.40 max	0.40 max	0.40 max
Copper, min, % when copper steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[A] Manganese content of 0.85 to 1.35 % and silicon content of 0.15 to 0.40 % is required for shapes over 426 lb/ft [634 kg/m].

[B] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % mananese above the specified maximum will be permitted up to the maximum of 1.35 %.

TABLE 3 Grade 50 [345] Chemical Requirements[A](Heat Analysis)

Maximum Diameter, Thickness, or Distance Between Parallel Faces, in. [mm]	Carbon, max, %	Manganese,[B] max, %	Phosphorus, max, %	Sulfur, max, %	Silicon[C]		Columbium,Vanadium and Nitrogen
					Plates to 1½-in. [40-mm] Thick, Shapes to 426 lb/ft [634 kg/m], Bars Zees and Rolled Tees, max, %[D]	Plates Over 1½-in. [40 mm] Thick and Shapes Over 426 lb/ft [634 kg/m], %	
4 [100]	0.23	1.35	0.04	0.05	0.40	0.15–0.40	see Footnote[E]

[A] Copper when specified shall have a minimum content of 0.20 % by heat analysis (0.18 % product analysis).

[B] Manganese, minimum by heat analysis of 0.80 % (0.75 % product analysis) shall be required for all plates over ⅜ in. [10 mm] in thickness; a minimum of 0.50 % (0.45 % product analysis) shall be required for plates ⅜ in. [10 mm] and less in thickness, and for all other products. The manganese to carbon ratio shall not be less than 2 to 1. A maximum of manganese of 1.50 % is permissible, with an associated reduction of the carbon maximum of 0.03 %.

[C] Silicon content in excess of 0.40 % by heat analysis must be negotiated.

[D] Bars over 1½ in. [40 mm] in diameter, thickness, or distance between parallel faces, shall be made by a killed steel practice.

[E] Alloy content shall be in accordance with one of the following types, and the contents of the applicable elements shall be reported.

Type	Elements	Heat Analysis, %
1	Columbium[A]	0.005–0.05[B]
2	Vanadium	0.01–0.15
3	Columbium[A]	0.005–0.05[B]
	Vanadium	0.01–0.15
	Columbium plus vanadium	0.02–0.15[C]
4	Vanadium	0.01–0.15[D]
	Nitrogen	0.015 max[D]

[A] Columbium shall be restricted to Grade 50 [345] plate, bar, zee, and rolled tee thickness of ¾ in. [20 mm] max, and to shapes of Groups 1 and 2 (see Table A of Specification A 6/A 6M) unless killed steel is furnished. Killed steel shall be confirmed by a statement of killed steel on the test report, or by a report of the presence of a sufficient quantity of a strong deoxidizing element, such as silicon at 0.10 % or higher, or aluminum at 0.015 % or higher.

[B] Product analysis limits = 0.004 to 0.06 %.

[C] Product analysis limits = 0.01 to 0.16 %.

[D] The vanadium to nitrogen ratio shall be 4 to 1 or greater.

TABLE 4 Grade 50W [345 W] Chemical Requirements (Heat Analysis)

NOTE 1—Types A, B, and C are equivalent to Specification A 588/A 588M Grades A, B, and C, respectively.

Element	Composition, %[A]		
	Type A	Type B	Type C
Carbon	0.19 max	0.20 max	0.15 max
Manganese	0.80–1.25	0.75–1.35	0.80–1.35
Phosphorus	0.04 max	0.04 max	0.04 max
Sulfur	0.05 max	0.05 max	0.05 max
Silicon	0.30–0.65	0.15–0.50	0.15–0.40
Nickel	0.40 max	0.50 max	0.25–0.50
Chromium	0.40–0.65	0.40–0.70	0.30–0.50
Copper	0.25–0.40	0.20–0.40	0.20–0.50
Vanadium	0.02–0.10	0.01–0.10	0.01–0.10

[A]Weldability data for these types have been qualified by FHWA for use in bridge construction.

requirements of this specification. All mechanical property tests shall be repeated when the material is resubmitted for inspection.

11. Atmospheric Corrosion Resistance

11.1 Steels meeting this specification provide two levels of atmospheric corrosion resistance:

11.1.1 Steel grades without suffix provide a level of atmospheric corrosion resistance typical of carbon or alloy steel without copper.

11.1.2 The steel for Grades 50W [345W], HPS 50W [HPS 345W], and HPS 70W [HPS 485W] shall have an atmospheric corrosion resistance index of 6.0 or higher, calculated from the heat analysis in accordance with Guide G 101-Predictive Method Based on the Data of Larabee and Coburn (see Note 3). When properly exposed to the atmosphere, these steels can be used bare (unpainted) for many applications. The steel for Grade 100W [690W] provides an improved level of atmospheric corrosion resistance over alloy steel without copper.

NOTE 3—For methods of estimating the atmospheric corrosion resistance of low-alloy steels, see Guide G 101.

The user is cautioned that the Guide G 101 predictive equation (Predictive Method Based on the Data of Larabee and Coburn) for calculation of an atmospheric corrosion resistance index has only been verified for the composition limits stated in that guide.

12. Marking

12.1 In addition to the marking requirements of Specification A 6/A 6M, material identification shall also include the composition type for Grades 50W [345W], 100 [690] and 100W [690W].

13. Keywords

13.1 alloy; atmospheric corrosion resistance; bars; bridges; carbon; high-strength; low-alloy; plates; quenched; shapes; steel; structural steel; tempered