The Engineering Society
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Cooperative Engineering Program

SAE J1442 DEC88

High-Strength, Hot-Rolled Steel Plates, Bar and Shapes

SAE Recommended Practice
Reaffirmed December 1988

Submitted for Recognition as an American National Standard

The Engineering Society For Advancing Mobility Land Sea Air and Space ®

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MATERIALS PRACTICE

Submitted for recognition as an American National Standard

SAE J1442

Issued June 1984
Reaffirmed December 1988

Reaffirming J1442 JUN84

HIGH-STRENGTH, HOT-ROLLED STEEL PLATES, BAR AND SHAPES

NOTE: High-strength, low-alloy plate, bar, and shape products detailed in this recommended practice were previously included in SAE J410. Sheet and strip products were also included in J410 but have been transferred to a separate recommended practice, SAE J1392.

1. SCOPE:

This recommended practice covers five levels of high-strength carbon and high-strength, low-alloy steel plates, bars, and shapes for structural use.

2. INTRODUCTION:

High-strength steel discussed in this recommended practice involves hot-rolled plates, bars, structural shapes, and bar size shapes. The strength is achieved through chemical composition and hot-rolling practice; it is not achieved through quenching and tempering or additional rolling operations. The primary use of high-strength steel is based on the mechanical properties which are significantly greater than those of plates, bars, and shapes produced without special attention to chemical composition and hot-rolling practice.

The five strength levels are 42, 50, 60, 70, and 80 ksi, or 290, 345, 415, 480, and 550 MPa minimum yield point. Different chemical compositions are used to achieve the specified mechanical properties. In some cases there are significant differences in chemical composition for the same strength level, depending on the fabricating requirements, that is, weldability, formability, toughness, tensile strength, and economics. Because the chemical compositions may vary significantly among the producers, despite the required mechanical properties being the same, it is important that the fabricator consult with the producer to determine the relative effects of the producer's composition on the forming, welding, and field service requirements.

The products within the scope of this recommended practice include the following:

2.1 Plates: Flat, hot-rolled steel (cut length only) greater than 8 in (204 mm) wide and greater than 0.230 in (5.8 mm) thick, and greater than 48 in (1220 mm) wide and greater than 0.179 in (4.6 mm) thick.

2.2 Bars: Rounds, squares, and hexagons of all sizes (cut length only), flats 0.203 in (5.2 mm) and greater in thickness but not greater than 6 in (153 mm) wide, and flats greater than 0.229 in (5.8 mm) thick and over 6 in (153 mm) to 8 in (204 mm) wide.

2.3 Structural Shapes: Hot-rolled flanged sections having at least one dimension of the cross section 3 in (76 mm) or greater. (Size groupings for tensile property classification are listed in ASTM A 6 Table A.)

2.4 Bar Size Shapes: Hot-rolled flanged sections having a maximum dimension of the cross section less than 3 in (76 mm).

3. GENERAL INFORMATION:

The specific grades are identified by the minimum yield point expressed in ksi, that is, 42, 50, 60, 70, and 80, or in MPa, that is, 290, 345, 415, 480, and 550. They are further identified at some strength levels with the suffixes A, W, and F. Chemical composition and processing variables are the bases for the suffix differences.

The A suffix generally identifies the relatively higher carbon compositions compared to the W and F suffix grades. Also, the A suffix grades specify a difference between the minimum yield point and the minimum tensile strength of at least 15 ksi or 105 MPa.

The W suffix identifies a grade with improved atmospheric corrosion resistance approximately four times that of carbon steel. The W suffix steels specify a difference between the minimum yield point and the minimum tensile strength of 20 ksi or 135 MPa.

The F suffix grades are the most formable grades in this practice. They are characterized by lower carbon content than the A and W suffix grades, and are normally made to killed steel fine grain and sulfide inclusion control practices. Due to the lower carbon content, the difference between the yield point and tensile strength is generally less than the difference in the A and W suffix grades. The F suffix grades, which normally are available only in Plates and Bar Size Flats, specify a difference between minimum yield point and minimum tensile strength of 10 ksi or at least 65 MPa although some producers use a chemical composition that provides differences of approximately 15 ksi or 105 MPa. It is important to note that these grades possess superior formability at their respective strength levels. The relatively smaller difference between the yield point and tensile strength does not lessen this high degree of formability.

When killed steel is required, the suffix K should follow the grade designation, 42AK (290AK) or 50AK (345AK) or 60AK (415AK).

3. (Continued):

Because these steels are characterized by their special mechanical properties obtained in the hot-rolled condition, they are not intended for any heat treatment by the purchaser either before, during, or after fabrication. The fabricator should not subject these steels to such heat treatments without assuming responsibility for the resulting mechanical properties. For certain applications, these steels may be annealed, normalized, or stress relieved with some effect on the mechanical properties; it is recommended that prior to such heat treatments, the purchaser should consult the producer to determine the need for and the effect on mechanical properties.

All grades and chemical compositions discussed in the practice are weldable despite the differences in carbon, manganese, and alloying additions. Because of the aforementioned variations in composition from one producer to another, it is advisable to discuss with the producers the features of their chemical composition relative to the various types of welding and any special consideration for each application.

These steels, because of their high strength-to-weight ratio, and in certain cases, abrasion resistance, are adapted particularly for use in mobile equipment and other structures where substantial weight savings are generally desirable.

4. MECHANICAL PROPERTIES:

The mechanical properties of these steels are shown in Tables 1A and 1B. If thicknesses greater than those shown in the table are required, consultation with the producers regarding availability and characteristics is suggested.

Present steel industry practice is to express the yield point of these grades rather than the yield strength. Such determination is by drop of beam or halt of the pointer method, autographic diagram method, or the total extension under load method as described in ASTM A 370, Standard Methods and Definitions for Mechanical Testing of Steel Products. Unless otherwise specified, this procedure is acceptable for material supplied in this report, and the use of an extensometer is not required. It is suggested that any disagreement between the seller and purchaser over the yield point value of a given lot be resolved by the 0.2% offset or the 0.5% extension under load methods, also described in ASTM A 370.

5. CHEMICAL COMPOSITION:

The chemical composition (heat analysis) of steel furnished to this practice shall conform to Table 2.

5. (Continued):

Because the chemical compositions vary significantly among the producers despite the required mechanical properties being the same, it is advisable for the purchaser to discuss specific compositions with each producer, especially if welding, atmospheric corrosion, and/or forming are critical factors. The commonly used alloying elements are, in alphabetical order: chromium, columbium (niobium), copper, molybdenum, nickel, titanium, vanadium, and zirconium. Choice of, and limits for, the alloying additions, other than those shown in Table 2, which are necessary to attain the required properties, may be specified by mutual agreement between purchaser and producer at the time of ordering. Once specified, they may not be changed without both parties' consent.

It should be noted that the thinner section thicknesses of the 42 (290), 50 (345), and 60 (415) grades are usually made as semi-killed. However, they are also available as killed steel made to a fine grain practice.

6. SUGGESTED BENDING PRACTICE:

The suggested cold forming practice is to avoid bends with an inside radius less than that shown in Table 3. These minimum forming radii for 90 deg bends have been established by experience using press brake bending in a direction parallel to the direction of final rolling ("hard way" bends). Should bending be accomplished across the direction of final rolling, slightly tighter radii could be used. Where design conditions permit, however, users are encouraged to utilize a slightly larger radius than that shown as an added safety factor. In any bending, it is presupposed that reasonably good forming practices will be used.

It should be noted that all steel has a tendency to crack when bent on a sheared or gas cut edge. This is not to be considered a fault of the steel, but rather a function of the induced cold work or heat affected zone. Where bends are to be made on a sheared edge, best performance is attained when the shear burr is located on the inside of the bend.

7. DIMENSIONAL TOLERANCES:

Standard manufacturing tolerances for dimensions, as shown in the latest edition of ASTM A 6, General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars of Structural Use, shall apply.

8. RELATIVE PERFORMANCE IN WELDING, FORMING AND TOUGHNESS:

Table 4 lists the relative performance of the grades when welding, forming, and toughness are important considerations. These are approximate ratings and reflect only the relative performance to each other; no attempt has been made to compare the grades shown in this practice to grades outside the limits of this practice.

TABLE 1A - Mechanical Properties[a,b]—Plates, Bars, Bar Size Shapes

Grade	Nominal Maximum Thickness		Yield Point[c] Minimum		Tensile Strength[d] Minimum		Elongation[e,f] % Minimum 8 in[g] 2 in	
	in	mm	ksi	MPa	ksi	MPa	(200 mm)	(50 mm)
42A	4	100	42	290	60	415	20	24
50A	2	50	50	345	65	450	18	21
50W	4[h]	100[h]	50	345	70	480	18	21
50F	3/4	19	50	345	60	415	20	—
60A	1 1/2	38	60	415	75	520	16	18
60F	3/4	19	60	415	70	480	17	—
70F	3/4	19	70	480	80	550	14	—
80F	5/8	16	80	550	90	620	12	—

[a]For plates wider than 24 in (610 mm), the test specimen is taken in the transverse direction.
[b]Mechanical testing (location, number of tests, preparation, and method) is to be in accordance with the latest revision of ASTM A 6.
[c]May be reported as yield strength as measured by the 0.2% offset or 0.5% extension under load method.
[d]Some applications may require a maximum tensile strength. In such cases, the following values must be determined from the producer for acceptance prior to issuing a purchase order:

Grade	Tensile Strength, Maximum ksi	MPa
42A	90	620
50A	95	660
50W	95	660
50F	90	620
60A	100	690
60F	95	660
70F	105	720
80F	115	790

[e]When ordered as floor plate (raised pattern), elongation requirements are not applicable.
[f]Because plates wider than 24 in (610 mm) are tested in the transverse direction, the elongation requirement is reduced two percentage points for all Grade 50 classes and three percentage points for all classes of Grades 60, 70, and 80.
[g]For material under 5/16 in or 8 mm in thickness or diameter, as represented by the test specimen, a deduction of 1.25 percentage points from the elongation percentage shown in the table shall be made for each decrease of 1/32 in or 0.8 mm of the specified thickness or diameter below 5/16 in or 8 mm.
[h]When ordered to 0.15% phosphorus maximum, maximum thickness generally available is 1/2 in or 13 mm.

TABLE 1B - Mechanical Properties[a]—Structural Shapes

Grade	Nominal Maximum Size ASTM Group[b]	Yield Point[c] Minimum		Tensile Strength Minimum		Elongation % Minimum	
		ksi	MPa	ksi	MPa	8 in[d] (200 mm)	2 in (50 mm)
42A	5	42	290	60	415	20	24[f]
50A	5	50	345	65	450	18	21[f]
50W	5[e]	50	345	70	480	18	21[g]
60A	2	60	415	75	520	16	18

[a]Mechanical testing (location, number of tests, preparation and method) is to be in accordance with the latest revision of ASTM A 6.
[b]Refer to ASTM A 6 Table A.
[c]May be reported as yield strength as measured by the 0.2% offset or 0.5% extension under load method.
[d]For material under 5/16 in or 8 mm in thickness or diameter, as represented by the test specimen, a deduction of 1.25 percentage points from the elongation percentage shown in the table shall be made for each decrease of 1/32 in or 0.8 mm of the specified thickness or diameter below 5/16 in or 8 mm.
[e]When ordered to 0.15% phosphorus maximum, maximum shape thickness available is 1/2 in (13 mm).
[f]For wide flange shapes over 426 lb/ft (634 kg/m), percent elongation in 2 in (50 mm) of 19 minimum applies.
[g]For wide flange shapes over 426 lb/ft (634 kg/m), percent elongation in 2 in (50 mm) of 18 minimum applies.

TABLE 2 - Chemical Composition[a], Heat Analysis

Grade	Product P-Plate B-Bar S-Shape	Thickness in (mm)	Elements, %[b,c,d,e,f]			Usual Deoxidation[h]	
			C	Mn	Si	Up to 1-1/2 in (38 mm)	Over 1-1/2 in (38 mm)
42A	P and B	to 1-1/2 in (38 mm) incl	0.21	1.35	0.90	SK	—
	P and B	over 1-1/2 in (38 mm) to 4 in (102 mm) incl	0.21	1.35	0.10/0.90	—	K
	S	all	0.24	1.35	0.40	SK	K
50A	P and B	to 1-1/2 in (38 mm) incl	0.22	1.35	0.90	SK	—
	P and B	over 1-1/2 in (38 mm) to 2 in (51 mm) incl	0.23	1.35	0.10/0.90	—	K
	S	all	0.23	1.35	0.40	SK	K
50W[g]	P and B	to 1-1/2 in (38 mm) incl	0.20	1.35	0.90	K	—
	P and B	over 1-1/2 in (38 mm) to 2 in (51 mm) incl	0.20	1.35	0.10/0.90	—	K
	S	all	0.20	1.35	0.10/0.90	—	K
50F	P	to 3/4 in (19 mm) incl	0.18	1.65	0.90	K	—
60A	P and B	to 3/4 in (19 mm) incl	0.24	1.35	0.90	SK	—
	P and B	over 3/4 in (19 mm) to 1-1/2 in (38 mm) incl	0.26	1.35	0.90	K	—
	S	all	0.26	1.35	0.30	SK	—
60F	P	to 3/4 in (19 mm) incl	0.18	1.65	0.90	K	—
70F	P	to 3/4 in (19 mm) incl	0.18	1.65	0.90	K	—
80F	P	to 5/8 in (16 mm) incl	0.18	1.65	0.90	K	—

[a]The choice and use of alloying elements combined with C, Mn, and Si within the limits prescribed to conform to the mechanical properties and/or to enhance the atmospheric corrosion resistance may vary by producer. Elements commonly added include: chromium, copper, molybdenum, nickel, columbium (niobium), vanadium, titanium, and zirconium. The alloys used shall be reported to the purchaser. Maximum limits may be specified for the alloying elements by mutual agreement between purchaser and producer at the time of order.

[b]Percent maximum unless range is shown in table.

[c]All phosphorus contents are 0.04% maximum, except for all F grades which are produced 0.025% maximum, and under certain conditions of Grade 50W (see Note g below).

[d]All sulfur contents are 0.05% maximum, except for all F grades which are produced to 0.035% maximum.

[e]Copper content of 0.20% minimum may be specified for Grades A and F.

[f]All grades normally exhibit fine ferritic grain; should austenitic grain size be a consideration, the producer should be consulted. These steels contain at least one of the following grain refining elements: aluminum, columbium (niobium), vanadium, titanium.

[g]When the maximum phosphorus is increased to 0.15%, the maximum carbon is 0.15%, and is limited to a thickness of 1/2 in (13 mm) inclusive.

[h]SK—semi-killed, K—killed.

TABLE 3 - Suggested Minimum Inside Radii for 90 Deg Cold Bending - Ratio of Bend Radius to Thickness

Grade	Thickness of Material, in (mm) To 1/4 (6.3) incl	Over 1/4 (6.3) To 1/2 (12.7) incl	Over 1/2 (12.7) To 3/4 (19) incl
42A	1	2	—
50A	2.5	2.5	—
50W	2.5	3	—
50F	1	1	1.5
60A	3.5	3.5	—
60F	1.5	1.5	2
70F	2	2.5	3
80F	2	2.5	3[a]

[a]Available only to 5/8 in (16 mm).

TABLE 4 - Approximate Relative Performances[a,b]
(in order of decreasing performance)

Weldability	Formability	Toughness
50F	50F	42AK
42A and 42AK	42AK	42A
50A and 50AK	50AK	50F
50W	42A	50AK
60F	50A	50W
60A and 60AK	50W	50A
70F	60F	60F
80F	60AK	60AK
	70F	60A
	60A	70F
	80F	80F

[a]When phosphorus is intentionally added, the grade loses ranking in all three qualities.
[b]All producers' product may not follow the above sequences.