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## STEEL REINFORCEMENT FOR CONCRETE MASONRY

## TEK 12-4D

Reinforcement & Connectors (2006)

**Keywords:** allowable stress, ASTM specifications, corrosion protection, development, embedment, joint reinforcement, reinforcing bars, reinforcing steel, strength design, wall ties, wire, working stress

### INTRODUCTION

Reinforcement in concrete masonry walls increases strength and ductility, increases resistance to applied loads, and in the case of horizontal reinforcement, also provides increased resistance to shrinkage cracking. This TEK covers non-prestressed reinforcement for concrete masonry construction. Prestressing steel is discussed in *Post-Tensioned Concrete Masonry Wall Construction*, TEK 3-14 (ref. 1). Unless otherwise noted, the information is based on the 2003 *International Building Code* (IBC) (ref. 2). For masonry design and construction, the IBC references *Building Code Requirements for Masonry Structures* and *Specification for Masonry Structures* (MSJC Code and Specification) (refs. 4, 5). In some cases, the IBC has adopted provisions different from the MSJC provisions. These instances have been noted where applicable.

### MATERIALS

Reinforcement used in masonry is principally reinforcing bars and cold-drawn wire products. Wall anchors and ties are

usually formed of wire, metal sheets or strips. Table 1 lists applicable ASTM Standards governing steel reinforcement, as well as nominal yield strengths for each steel type.

### Reinforcing Bars

Reinforcing bars are available in the United States in eleven standard bar sizes designated No. 3 through 11, No. 14 and No. 18 (M#10-36, M#43, M#57). The size of a reinforcing bar is designated by a number corresponding to its nominal diameter. For bars designated No. 3 through No. 8 (M#10-25), the number indicates the diameter in eighths of an inch (mm), as shown in Table 2.

To help address potential problems associated with reinforcement congestion and grout consolidation, the IBC limits the reinforcing bar diameter to the lesser of one-eighth the nominal member thickness, and one-fourth the least dimension of the cell, course or collar joint into which it is placed. For typical single wythe walls, this corresponds to a maximum bar size of No. 8, 9 and 11 for 8-, 10- and 12-in. walls, respectively (M#25, 29 and 36 for 203-, 254- and

**Table 1—Reinforcement Used in Masonry (ref. 2)**

Reinforcement type:	Governing specification (ref.)	Material	Grade	Minimum yield strength, ksi (MPa)
Reinforcing bars	ASTM A 615 <sup>1</sup> (6)	Billet-steel	40, 60	40, 60 (300, 420)
	ASTM A 706 <sup>1</sup> (7)	Low-alloy steel	60	60 (420)
	ASTM A 767 (8)	Zinc-coated steel <sup>2</sup>		
	ASTM A 775 (9)	Epoxy-coated steel <sup>2</sup>		
	ASTM A 996 (10)	Rail-steel and axle-steel	40, 50, 60	40, 50, 60 (300, 350, 420)
Joint reinforcement	ASTM A 951 (11)	Joint reinforcement		70 (485)
	ASTM A 580 (Type 304) (12)	Stainless/heat-resisting wire		90 (620)
	ASTM A 496 (13)	Deformed steel wire		75 (515)

<sup>1</sup> Weldability is not part of the specification; may be subject to agreement with supplier.

<sup>2</sup> The reinforcing bars to be coated must meet the requirements of A 615, A 706 or A 996, as appropriate.

305-mm walls). In addition, the following limits apply:

- maximum bar size is No. 11 (M#36),
- the area of vertical reinforcement may not exceed 6% of the grout space area (i.e., about 1.26 in.<sup>2</sup>, 1.81 in.<sup>2</sup>, or 2.40 in.<sup>2</sup> of vertical reinforcement for 8-, 10- and 12-in. concrete masonry, respectively (815, 1,170 or 1,550 mm<sup>2</sup> for 203-, 254- and 305-mm units, respectively), and
- for masonry designed using strength design procedures, the maximum bar size is No. 9 (M#29) and the maximum area of reinforcement is 4% of the cell area (i.e., about 0.84 in.<sup>2</sup>, 1.21 in.<sup>2</sup>, or 1.61 in.<sup>2</sup> of vertical reinforcement for 8-, 10- and 12-in. concrete masonry, respectively (545, 781 or 1,039 mm<sup>2</sup> for 203-, 254- and 305-mm units, respectively).

The prescriptive limits on reinforcement sizes, above, are construction-related. Additional design limits to prevent over-reinforcing and brittle failures may also apply depending on the design method used and the design loads resisted. Manufacturers mark the bar size, producing mill identification and type of steel on reinforcing bars (see Figure 1). Note that the bar size indicates the size in SI units per ASTM standards.

The ASTM standards include minimum requirements for various physical properties including yield strength and stiffness. While not all reinforcing bars have a well-defined yield point, the modulus of elasticity,  $E_s$ , is roughly the same for all reinforcing steels and for design purposes is taken as 29,000,000 psi (200 GPa).

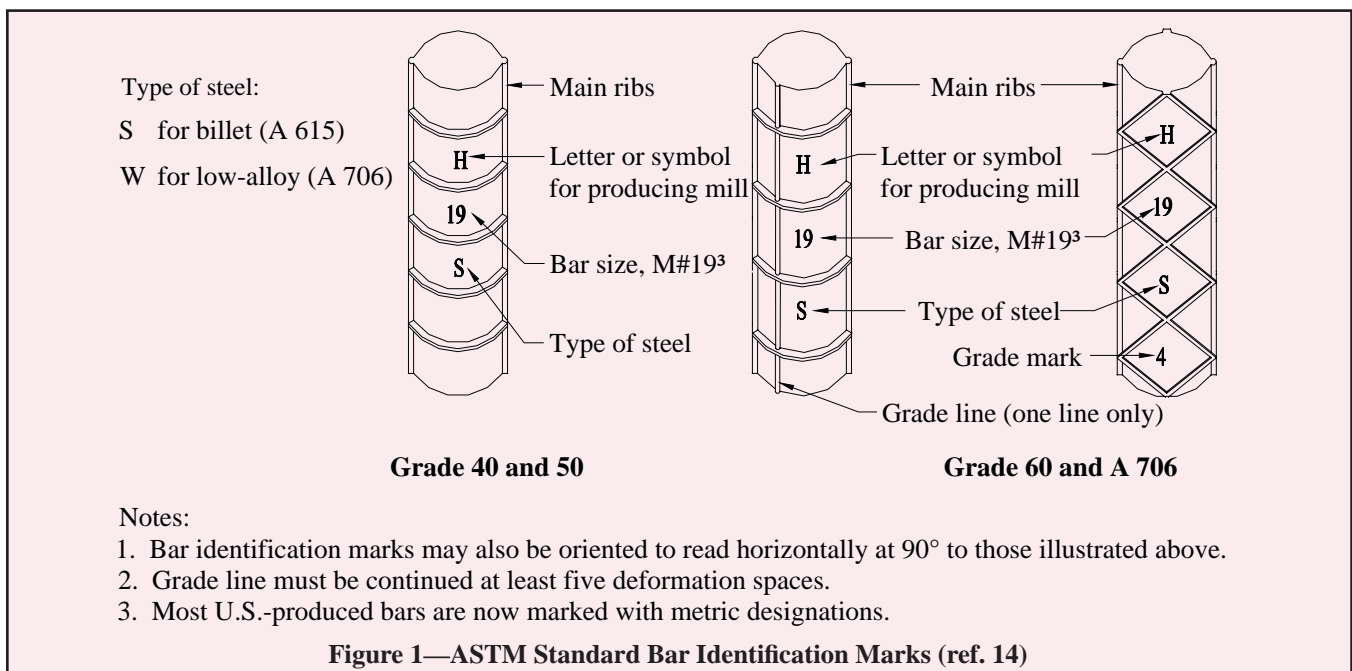
When designing by the allowable stress design method, allowable tensile stress is limited to 20,000 psi (138 MPa) for Grade 40 or 50 reinforcing bars and 24,000 psi (165 MPa) for Grade 60 reinforcing bars. For reinforcing bars enclosed in ties, such as those in columns, the allowable compressive stress is limited to 40% of the specified yield strength, with a maximum of 24,000 psi (165 MPa). For strength design, the nominal yield strength of the reinforcement is used to size and distribute the steel.

### Cold-Drawn Wire

Cold-drawn wire for joint reinforcement, ties or anchors varies from W1.1 to W4.9 (MW7 to MW32) with the most popular size being W1.7 (MW11). Table 3 shows standard wire sizes and properties. Because the IBC limits the size of joint reinforcement to one half the joint thickness, the practical limit for wire diameter is  $\frac{3}{16}$  in. (W2.8, 4.8 mm, MW18) for a  $\frac{3}{8}$  in. (9.5 mm) bed joint. Wire for masonry is plain with the exception that side wires for joint reinforcement are deformed by means of knurling wheels.

Stress-strain characteristics of reinforcing wire have been determined by extensive testing programs. Not only is the yield strength of cold-drawn wire close to its ultimate strength, but the location of the yield point is not clearly indicated on the stress-strain curve. ASTM A 82 (ref. 15) defines yield as the stress determined at a strain of 0.005 in./in. (mm/mm).

Bar size, No.	Weight, lb/ft (kg/m)	Diameter, in. (mm)	Cross-sectional area, in. <sup>2</sup> (mm <sup>2</sup> )	Perimeter, in. (mm)
3 (M#10)	0.376 (0.560)	0.375 (9.5)	0.11 (71)	1.178 (30)
4 (M#13)	0.668 (0.994)	0.500 (13)	0.20 (129)	1.571 (40)
5 (M#16)	1.043 (1.552)	0.625 (16)	0.31 (199)	1.963 (50)
6 (M#19)	1.502 (2.235)	0.750 (19)	0.44 (284)	2.356 (60)
7 (M#22)	2.044 (3.042)	0.875 (22)	0.60 (387)	2.749 (70)
8 (M#25)	2.670 (3.973)	1.000 (25)	0.79 (510)	3.142 (80)
9 (M#29)	3.400 (5.060)	1.128 (29)	1.00 (645)	3.544 (90)
10 (M#32)	4.303 (6.404)	1.270 (32)	1.27 (819)	3.990 (101)
11 (M#36)	5.313 (7.907)	1.410 (36)	1.56 (1,006)	4.430 (113)



**Table 3—Properties of Wire For Masonry**

Wire size	Nominal diameter <sup>1</sup> , in. (mm)	Nominal area, in. <sup>2</sup> (mm <sup>2</sup> )	Nominal perimeter, in. (mm)
W1.1 (11 gage, MW 7)	0.121 (3.1)	0.011 (7.1)	0.380 (9.6)
W1.7 (9 gage, MW 11)	0.148 (3.8)	0.017 (11)	0.465 (12)
W2.1 (8 gage, MW 13)	0.162 (4.1)	0.020 (13)	0.509 (13)
W2.8 (3/16 in., MW 17)	0.187 (4.8)	0.027 (18)	0.587 (15)
W4.9 (1/4 in., MW 32)	0.250 (6.4)	0.049 (32)	0.785 (20)

<sup>1</sup> ASTM A 82 (ref. 15) permits variation of  $\pm 0.003$  in. (0.08 mm) from diameter shown.

**CORROSION PROTECTION**

Grout, mortar and masonry units usually provide adequate protection for embedded reinforcement provided that minimum cover and clearance requirements are met. Reinforcement with a moderate amount of rust, mill scale or a combination is allowed to be used without cleaning or brushing, provided the dimensions and weights (including heights of deformations) of a cleaned sample are not less than those required by the applicable ASTM standard. When additional corrosion protection is needed, reinforcement can be galvanized or epoxy coated.

**Joint Reinforcement**

Carbon steel can be protected from corrosion by coating the steel with zinc (galvanizing). The zinc protects in two ways: first, as a barrier separating the steel from oxygen and water, and second during the corrosion process, the zinc is sacrificed before the steel is attacked. Increasing the zinc coating thickness improves the level of corrosion protection.

Required levels of corrosion protection increase with the severity of exposure. When used in exterior walls or in interior walls exposed to a mean relative humidity over 75%, carbon steel joint reinforcement must be hot-dip galvanized or epoxy-coated, or stainless steel joint reinforcement must be used. When used in interior walls exposed to a mean relative humidity less than or equal to 75%, it can be mill galvanized, hot-dip galvanized, or be stainless steel. The corresponding minimum protection levels are:

- Mill galvanized—ASTM A 641 (ref. 16) 0.1 oz/ft<sup>2</sup> (0.031 kg/m<sup>2</sup>)
- Hot-dip galvanized—ASTM A 153 (ref. 17), Class B, 1.5 oz/ft<sup>2</sup> (458 g/m<sup>2</sup>)
- Epoxy-coated—ASTM A 884 (ref. 18) Class A, Type 1  $\geq 7$  mils (175  $\mu$ m) (ref. 3). Note that both the 2003 IBC and 2002 MSJC code incorrectly identify Class B, Type 2 epoxy coated joint reinforcement, which is not applicable for masonry construction.

In addition, joint reinforcement must be placed so that longitudinal wires are embedded in mortar with a minimum cover of 1/2 in. (13 mm) when not exposed to weather or earth, and 5/8 in. (16 mm) when exposed to weather or earth.

**Reinforcing Bars**

A minimum amount of masonry cover over reinforcing bars is required to protect against steel corrosion. This masonry cover is measured from the nearest exterior masonry surface to the outermost surface of the reinforcement, and includes the thickness of masonry face shells, mortar and grout. The following minimum cover requirements apply:

- masonry exposed to weather or earth
  - bars larger than No. 5 (M#16) ..... 2 in. (51 mm)
  - No. 5 (M#16) bars or smaller..... 1 1/2 in. (38 mm)
- masonry not exposed to weather or earth .. 1 1/2 in. (38 mm)

**PLACEMENT**

Installation requirements for reinforcement and ties help ensure that elements are placed as assumed in the design, and that structural performance is not compromised due to mislocation. These requirements also help minimize corrosion by providing for a minimum amount of masonry and grout cover around reinforcing bars, and providing sufficient clearance for grout and mortar to surround reinforcement and accessories so that stresses can be properly transferred.

**Reinforcing Bars**

Tolerances for placing reinforcing bars are:

- variation from  $d$  for walls and flexural elements:
  - $d \leq 8$  in. (203 mm).....  $\pm 1/2$  in. (13 mm)
  - $8$  in. (203 mm)  $< d \leq 24$  in. (610 mm)  $\pm 1$  in. (25 mm)
  - $d > 24$  in. (610 mm).....  $\pm 1 1/4$  in. (32 mm)
- for vertical bars in walls .....  $\pm 2$  in. (51 mm) from the specified location along the length of the wall.

In addition, a minimum clear distance between reinforcing bars and the adjacent (interior of cell) surface of a masonry unit of 1/4 in. (6.4 mm) for fine grout or 1/2 in. (13 mm) for coarse grout must be maintained so that grout can flow around the bars.

**DEVELOPMENT**

Development length or anchorage is necessary to adequately transfer stresses between the reinforcement and the grout in which it is embedded. Reinforcing bars can be anchored by embedment length, hook or mechanical device. Reinforcing bars anchored by embedment length rely on interlock at the bar deformations and on sufficient masonry cover to prevent splitting from the reinforcing bar to the free surface. Detailed information and requirements for development, splice and standard hooks are contained in TEK 12-6, *Reinforcement Detailing Requirements for Concrete Masonry* (ref. 19).

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