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SPLICES, DEVELOPMENT AND STANDARD HOOKS FOR CONCRETE MASONRY

TEK 12-6
Reinforcement & Connectors (2007)

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INTRODUCTION

Building codes include requirements for minimum reinforcement development lengths and splice lengths, as well as requirements for standard hooks, to ensure the adequate transfer of stresses between the reinforcement and the masonry. This TEK presents these requirements, based on the provisions of both the 2003 and 2006 editions of the *International Building Code* (IBC) (refs. 1, 2). TEK 12-4D (ref. 3) includes basic material requirements, corrosion protection and placement tolerances for reinforcement used in concrete masonry construction. In addition, prestressing steel is discussed in *Post-Tensioned Concrete Masonry Wall Construction*, TEK 3-14 (ref. 4).

SPLICES AND DEVELOPMENT

Minimum development lengths are necessary to adequately transfer stresses between reinforcement and the grout or mortar in which it is embedded. Splicing of reinforcement serves a similar purpose; to adequately transfer stresses from one reinforcing bar to another.

Reinforcement can be developed by embedment length, hook, or mechanical anchoring device. The development of the reinforcing bars relies on mechanical interlock of the bar deformations, hook, and/or anchor along with sufficient masonry cover to prevent splitting of the masonry. Reinforcing bars may be spliced by lapping the reinforcement, by proprietary mechanical splices or by welding.

The required length of lap or development is determined according to the design procedure used and type of detail employed. In addition, these detailing requirements have been frequently revised in recent years. As a result, the minimum lap and development lengths can vary considerably from one code to the next as well as from one design method to another. For this reason, the following sections present the requirements for both the 2003 IBC and 2006 IBC for both allowable stress and strength design. Because the detailing requirements for these two codes can be significantly different, designers using the 2003 IBC are encouraged to compare these requirements to the corresponding 2006 IBC requirements.

ALLOWABLE STRESS DESIGN

2003 IBC Allowable Stress Design

By reference to the 2002 edition of *Building Code Requirements for Masonry Structures* (MSJC) (ref. 5), the 2003 IBC requires the minimum development length for reinforcing bars and wires designed by the allowable stress method to be calculated using Equation 1 (see Tables 1 and 2).

$$l_d = 0.0015 d_b F_s, \qquad \text{(Eqn. 1)}$$

but not less than 12 in. (305 mm) for bars or 6 in. (152 mm) for wires.

When epoxy coated bars or wires are used, the development length determined by Equation 1 is required to be increased by 50 percent.

Although development lengths and lap splice lengths have historically been assumed to be related and calculated in a similar manner, the 2003 IBC provides a unique design equation for determining the minimum length of lap for reinforcing bars, in accordance with Equation 2. Table 5 contains tabulated values for common design variables shown in Equation 2.

$$l_d = \frac{0.16 d_b^2 f_y \gamma}{K\sqrt{f'_m}} \quad \left(\text{SI: } l_d = \frac{1.95 d_b^2 f_y \gamma}{K\sqrt{f'_m}}\right), \qquad \text{(Eqn. 2)}$$

but not less than 15 in. (380 mm)

For use in Equation 2, the reinforcement size factor, γ, is taken equal to 1.0 for No. 3 through No. 5 (M#10–M#16) reinforcing bars; 1.4 for No. 6 and No. 7 (M#19 and M#22) reinforcing bars; and 1.5 for No. 8 and No. 9 (M#25 and M#29) reinforcing bars. Reinforcing bars larger than No. 9 (M#29) are required to be spliced using mechanical connectors. When noncontact lap splices are used, the bars must be spaced no farther apart than one-fifth the required length of lap nor more than 8 in. (203 mm).

As an alternative to lap splicing, reinforcing bars can be spliced by welding. Welded splices require the bars to be butted or shortly lapped and welded to develop in tension at least 125% of the specified yield strength of the bar. All welding is required to conform to AWS D 1.4 (ref. 6). In practice, however, welding tends to be an expensive splicing option.

Finally, mechanical splicing of reinforcement typically employs proprietary couplers specifically designed for this application. Mechanical splices are required to have the bars connected to develop in tension or compression, as required, at least 125% of the specified yield strength of the bar.

Reinforcing bars can also be spliced using end-bearing splices, but only in members containing closed ties, closed stirrups or spirals for bars subject to compression only. End-bearing splices rely on the transmission of compressive stress by bearing of square cut ends held in concentric contact by a suitable device. The bar ends are required to terminate in flat surfaces within 1$^1/_2$ degrees of a right angle to the axis of the bars and be fitted within 3 degrees of full bearing after assembly.

2006 IBC Allowable Stress Design

With the publication of the 2006 IBC, which in turn references the 2005 MSJC (ref. 7), the majority of the splicing and development detailing requirements have remained the same, with the notable exception that Equation 2 has been superseded for determining the minimum length of lap splices.

While the 2005 MSJC includes an equation to determine development length, which is also used to determine lap splice length, the 2006 IBC modifies the MSJC lap splice length.

Allowable Stress Design Development Lengths

Table 1—2003 IBC Allowable Stress Design Development Lengths (ref. 1)

Bar size	Minimum development length[A, B], in. (mm)
No. 3 (M#10)	14 (356)
No. 4 (M#13)	18 (457)
No. 5 (M#16)	23 (584)
No. 6 (M#19)	27 (686)
No. 7 (M#22)	32 (813)
No. 8 (M#25)	36 (914)
No. 9 (M#29)	41 (1,041)
No. 10 (M#32)	46 (1,168)
No. 11 (M#36)	51 (1,295)

[A] See Equation 1. Based on F_s = 24,000 psi (165 MPa) for Grade 60 reinforcement. Development length not less than 12 in. (305 mm).

[B] Development lengths are to be increased by 50% when epoxy coated reinforcement is used.

Table 2—2003 and 2006 IBC Allowable Stress Design Development Lengths for Wires (refs. 1, 2)

Wire size	Minimum development length[A, B], in. (mm)
W1.1 (11 gage, MW 7)	6 (152)
W1.7 (9 gage, MW 11)	7 (178)
W2.1 (8 gage, MW 13)	8 (203)
W2.8 ($^3/_{16}$ in., MW 17)	9 (229)
W4.9 ($^1/_4$ in., MW 32)	12 (305)

[A] See Equation 1. Based on F_s = 30,000 psi (207 MPa) for wire joint reinforcement. Development length not less than 6 in. (152 mm).

[B] Development lengths are to be increased by 50% when epoxy coated wire is used.

Table 3—2006 IBC Allowable Stress Design Development Lengths for Reinforcing Bars (ref. 2)

	Minimum development length[A], in. (mm) based on:					
	Bar in center of:				K =	
Bar size	6-in. (152-mm) CMU	8-in. (203-mm) CMU	10-in. (254-mm) CMU	12-in. (305-mm) CMU	1$^1/_2$ in. (38 mm)	2 in. (51 mm)
No. 3 (M #10)	16 (406) [B]	16 (406) [B]	16 (406) [B]	16 (406) [B]	19 (483)	16 (406) [B]
No. 4 (M#13)	21 (533) [B]	21 (533) [B]	21 (533) [B]	21 (533) [B]	34 (864)	26 (660)
No. 5 (M#16)	32 (813) [D]	26 (660) [B]	26 (660) [B]	26 (660) [B]	53 (1,346)	40 (1,016)
No. 6 (M#19)	61 (1,549) [D]	43 (1,092)	40 (1,016) [B]	40 (1,016) [B]	99 (2,515)	74 (1,880)
No. 7 (M#22)	NP [C]	60 (1,524)	46 (1,168)	46 (1,168) [B]	134 (3,404)	101 (2,565)
No. 8 (M#25)	NP [C]	92 (2,337) [D]	71 (1,803)	61 (1,549) [B]	202 (5,131)	151 (3,835)
No. 9 (M#29)	NP [C]	NP [C]	91 (2,311)	74 (1,880)	257 (6,528)	193 (4,902)
No. 10 (M#32)	NP [C]	NP [C]	NP [C]	95 (2,413)	325 (8,255)	244 (6,198)
No. 11 (M#36)	NP [C]	NP [C]	NP [C]	118 (2,997)	401 (10,185)	301 (7,645)

[A] See Equation 4. Based on f_y = 60,000 psi (414 MPa) for Grade 60 steel and f'_m = 1,500 psi (10.3 MPa).

[B] $K = 5d_b$ governs.

[C] Bar is too large for this wall; d_b exceeds $^1/_4$ of the least clear dimension of the cell to be grouted, $^1/_8$ of the nominal unit thickness, or 6% of the cell area to be grouted. Dimensions are based on specified minimum dimensions for a two-core, square core unit and take into account a cell taper of $^1/_4$ in. (6.4 mm) and mortar protrusions not exceeding $^1/_2$ in. (13 mm).

[D] Permitted only if mortar fins are removed from the cell to be grouted. Not permitted if mortar fins are not removed.

In accordance with the 2006 IBC, the minimum required lap length for spliced reinforcing bars is determined using Equation 3. Table 4 lists tabulated values.

$l_d = 0.002 d_b f_s$ (SI: $l_d = 0.29 d_b f_s$), (Eqn. 3)
but not less than 12 in. (305 mm) or $40d_b$, whichever is greater

Further, in regions of flexure where the design tensile stresses in the reinforcement, f_s, exceed 80% of the allowable steel tensile stress, F_s, the required length of lap determined by Equation 3 must be increased by 50%. Alternatively, equivalent means of stress transfer to accomplish the same 50% increase is permitted. Where epoxy coated bars are used, lap length is also required to be increased by 50%.

For wires, minimum development length is determined in accordance with Equation 1 (see Table 2). For reinforcing bars, however, the 2005 MSJC minimum development length was not modified by the IBC, and so is determined by Equation 4 (see Table 3).

$$l_d = \frac{0.13 d_b^2 f_y \gamma}{K\sqrt{f'_m}} \quad \left(\text{SI: } l_d = \frac{1.5 d_b^2 f_y \gamma}{K\sqrt{f'_m}}\right), \qquad \text{(Eqn. 4)}$$

but not less than 12 in. (305 mm)

For use in Equation 4, the reinforcement size factor, γ, is taken equal to 1.0 for No. 3 through No. 5 (M#10–M#16) reinforcing bars; 1.3 for No. 6 and No. 7 (M#19 and M#22) bars; and 1.5 for No. 8 through No. 11 (M#25–M#36) bars. When epoxy coated bars are used, the development length determined by Equation 4 is required to be increased by 50%.

Allowable Stress Design Lap Splice Lengths

Table 4—2006 IBC Allowable Stress Design Lap Splice Lengths (ref. 2)

Bar size	Minimum lap splice length[A, D], in. (mm)	Minimum lap splice length[B, D], in. (mm)
No. 3 (M#10)	15 (381)	27 (686)
No. 4 (M#13)	20 (508)	36 (914)
No. 5 (M#16)	25 (635)	45 (1,143)
No. 6 (M#19)	30 (762)	54 (1,372)
No. 7 (M#22)	35 (889)	63 (1,600)
No. 8 (M#25)	40 (1,016)	72 (1,829)
No. 9 (M#29)[C]	46 (1,168)	82 (2,083)

[A] See Equation 3. Based on the stresses in the steel, f_s, being limited to 80% of the allowable reinforcement tensile stress (F_s = 24,000 psi (165 MPa) for Grade 60 reinforcement). Lap splice length not less than 12 in. (305 mm) nor $40d_b$. Minimum lap lengths may be smaller in cases where $f_s < 0.8F_s$.
[B] Based on the stresses in the steel, f_s, taken equal to 100% of the allowable reinforcement tensile stress of 24,000 psi (165 MPa) for Grade 60 reinforcement. Lap splice length not less than 12 in. (305 mm) or $40d_b$.
[C] Bars larger than No. 9 (M#29) are required to be spliced by mechanical connectors.
[D] Lap splice lengths are to be increased by 50% when epoxy coated reinforcement is used.

Table 5—2003 IBC Allowable Stress Design Lap Splice Lengths (ref. 1)

	Minimum lap splice length[A], in. (mm) based on:					
	Bar in center of:				K =	
Bar size	6-in. (152-mm) CMU	8-in. (203-mm) CMU	10-in. (254-mm) CMU	12-in. (305-mm) CMU	$1^1/_2$ in. (38 mm)	2 in. (51 mm)
No. 3 (M #10)	19 (483) [B]	19 (483) [B]	19 (483) [B]	19 (483) [B]	24 (610)	19 (483) [B]
No. 4 (M#13)	25 (635) [B]	25 (635) [B]	25 (635) [B]	25 (635) [B]	42 (1,067)	31 (787)
No. 5 (M#16)	39 (991)	31 (787) [B]	31 (787) [B]	31 (787) [B]	65 (1,651)	49 (1,245)
No. 6 (M#19)	81 (2,057) [F]	57 (1,448)	53 (1,346) [B]	53 (1,346) [B]	131 (3,327)	98 (2,489)
No. 7 (M#22)	NP [C]	79 (2,007)	61 (1,549)	61 (1,549) [B]	178 (4,521)	133 (3,378)
No. 8 (M#25)	NP [C]	113 (2,870)	87 (2,210)	75 (1,905) [B]	248 (6,299)	186 (4,724)
No. 9 (M#29) [D]	NP [C]	NP [C]	112 (2,845)	91 (2,311)	316 (8,026)	237 (6,020)

[A] See Equation 2. Based on f_y = 60,000 psi (414 MPa) for Grade 60 steel, f'_m = 1,500 psi (10.3 MPa).
[B] $K = 5d_b$ governs.
[C] Bar is too large for this wall; d_b exceeds $^1/_4$ of the least clear dimension of the cell to be grouted, $^1/_8$ of the nominal unit thickness, or 6% of the cell area to be grouted. Dimensions are based on specified minimum dimensions for a two-core, square core unit and take into account a cell taper of $^1/_4$ in. (6.4 mm) and mortar protrusions not exceeding $^1/_2$ in. (13 mm).
[D] Bars larger than No. 9 (M#29) are required to be spliced by mechanical connectors.
[F] Permitted only if mortar fins are removed from the cell to be grouted. Not permitted if mortar fins are not removed.

STRENGTH DESIGN

2003 IBC Strength Design

By reference to the 2002 MSJC (ref. 5), the 2003 IBC requires the minimum development length and lap splice length for reinforcing bars designed by the strength method to be calculated by Equation 5 (see Table 7).

$$l_d = \frac{0.13 d_b^2 f_y \gamma}{\phi K \sqrt{f'_m}} \quad \left(\text{SI: } l_d = \frac{1.5 d_b^2 f_y \gamma}{\phi K \sqrt{f'_m}} \right), \qquad \text{(Eqn. 5)}$$

but not less than 12 in. (305 mm)

For use in Equation 5, the reinforcement size factor, γ, is taken equal to 1.0 for No. 3 through No. 5 (M#10–M#16) reinforcing bars; 1.4 for No. 6 and No. 7 (M#19 and M#22) reinforcing bars; and 1.5 for No. 8 and No. 9 (M#25 and M#29) reinforcing bars.

The 2003 IBC modifies the MSJC requirements for welded and mechanical splices as follows. The IBC stipulates that mechanical splices be classified as Type 1 or 2 according to Section 21.2.6.1 of ACI 318 (ref. 8). Type 1 splices may not be used within the plastic hinge zone nor within a beam-column joint of intermediate or special reinforced masonry shear walls or special moment frames.

Welded splices must be able to develop at least 125% of the bar's specified yield strength in tension or compression, as required. Welded splices must use ASTM A 706 (ref. 9) steel

Strength Design Development and Lap Splice Lengths

Table 6—2006 IBC Strength Design Development and Lap Splice Lengths (ref. 2)

Bar size	Minimum lap splice length[A], in. (mm) based on: Bar in center of: 6-in. (152-mm) CMU	8-in. (203-mm) CMU	10-in. (254-mm) CMU	12-in. (305-mm) CMU	K = 1$^1/_2$ in. (38 mm)	K = 2 in. (51 mm)
No. 3 (M #10)	16 (406) [B]	16 (406) [B]	16 (406) [B]	16 (406) [B]	19 (483)	16 (406) [B]
No. 4 (M#13)	21 (533) [B]	21 (533) [B]	21 (533) [B]	21 (533) [B]	34 (864)	26 (660)
No. 5 (M#16)	32 (813) [F]	26 (660) [B]	26 (660) [B]	26 (660) [B]	45 (1,143) [D]	40 (1,016)
No. 6 (M#19)	61 (1,549) [F]	43 (1,092)	40 (1,016) [B]	40 (1,016) [B]	54 (1,372) [D]	54 (1,372) [D]
No. 7 (M#22)	NP [C]	60 (1,524)	46 (1,168)	46 (1,168) [B]	63 (1,600) [D]	63 (1,600) [D]
No. 8 (M#25)	NP [C]	92 (2,337) [F]	71 (1,803)	61 (1,549) [B]	72 (1,829) [D]	72 (1,829) [D]
No. 9 (M#29)[E]	NP [C]	NP [C]	82 (2,083) [D]	74 (1,880)	82 (2,083) [D]	82 (2,083) [D]

[A] See Equation 6. Based on f_y = 60,000 psi (414 MPa) for Grade 60 steel and f'_m = 1,500 psi (10.3 MPa).
[B] $K = 5d_b$ governs.
[C] Bar is too large for this wall; d_b exceeds $^1/_4$ of the least clear dimension of the cell to be grouted, $^1/_8$ of the nominal unit thickness, or 4% of the cell area to be grouted. Dimensions are based on specified minimum dimensions for a two-core, square core unit and take into account a cell taper of $^1/_4$ in. (6.4 mm) and mortar protrusions not exceeding $^1/_2$ in. (13 mm).
[D] Maximum splice length of $72d_b$ governs.
[E] Strength design provisions do not permit the use of reinforcing bars larger than No. 9 (M#29) (ref. 2).
[F] Permitted only if mortar fins are removed from the cell to be grouted. Not permitted if mortar fins are not removed.

Table 7—2003 IBC Strength Design Development and Lap Splice Lengths (ref. 1)

Bar size	Minimum lap splice length[A], in. (mm) based on: Bar in center of: 6-in. (152-mm) CMU	8-in. (203-mm) CMU	10-in. (254-mm) CMU	12-in. (305-mm) CMU	K = 1$^1/_2$ in. (38 mm)	K = 2 in. (51 mm)
No. 3 (M #10)	19 (483) [B]	19 (483) [B]	19 (483) [B]	19 (483) [B]	24 (610)	19 (483) [B]
No. 4 (M#13)	25 (635) [B]	25 (635) [B]	25 (635) [B]	25 (635) [B]	42 (1,067)	31 (787)
No. 5 (M#16)	39 (991) [E]	31 (787) [B]	31 (787) [B]	31 (787) [B]	65 (1,651)	49 (1,245)
No. 6 (M#19)	81 (2,057) [E]	57 (1,448)	53 (1,346) [B]	53 (1,346) [B]	131 (3,327)	98 (2,489)
No. 7 (M#22)	NP [C]	79 (2,007)	61 (1,549)	61 (1,549) [B]	178 (4,521)	133 (3,378)
No. 8 (M#25)	NP [C]	113 (2,870) [E]	87 (2,210)	75 (1,905) [B]	248 (6,299)	186 (4,724)
No. 9 (M#29) [D]	NP [C]	NP [C]	112 (2,845)	91 (2,311)	316 (8,026)	237 (6,020)

[A] See Equation 5. Based on f_y = 60,000 psi (414 MPa) for Grade 60 steel, f'_m = 1,500 psi (10.3 MPa) and ϕ = 0.80.
[B] $K = 5d_b$ governs.
[C] Bar is too large for this wall; d_b exceeds $^1/_4$ of the least clear dimension of the cell to be grouted, $^1/_8$ of the nominal unit thickness, or 4% of the cell area to be grouted. Dimensions are based on specified minimum dimensions for a two-core, square core unit and take into account a cell taper of $^1/_4$ in. (6.4 mm) and mortar protrusions not exceeding $^1/_2$ in. (13 mm).
[D] Strength design provisions do not permit the use of reinforcing bars larger than No. 9 (M#29) (ref. 2).
[E] Permitted only if mortar fins are removed from the cell to be grouted. Not permitted if mortar fins are not removed.

reinforcement. Welded splices are not permitted to be used in plastic hinge zones of intermediate or special reinforced walls nor in special moment frames of masonry.

2006 IBC Strength Design

For development and lap splice length requirements, the 2006 IBC references the 2005 MSJC (see Equation 6 and Table 6), but limits the maximum length to $72d_b$.

$$l_d = \frac{0.13 d_b^2 f_y \gamma}{K\sqrt{f'_m}} \quad \left(\text{SI: } l_d = \frac{1.5 d_b^2 f_y \gamma}{K\sqrt{f'_m}}\right), \qquad \text{(Eqn. 6)}$$

but not less than 12 in. (305 mm) and not more than $72d_b$,

For Equation 6, the reinforcement size factor, γ, is taken equal to 1.0 for No. 3 through No. 5 (M#10–M#16) reinforcing bars; 1.3 for No. 6 and No. 7 (M#19, M#22) bars; and 1.5 for No. 8 and No. 9 (M#25, M#29) bars. When epoxy coated bars are used, the development length determined by Equation 6 is required to be increased by 50%. Bars spliced by noncontact lap splices must be spaced no farther apart than one-fifth the required length of lap and no more than 8 in. (203 mm).

The 2006 IBC includes the same modifications for mechanical and weld splices listed under *2003 IBC Strength Design*.

STANDARD HOOKS

Figure 1 illustrates the requirements for standard hooks, when reinforcing bars are anchored by hooks or by a combination of hooks and development length. Table 8 lists minimum dimensions and equivalent embedment lengths for standard hooks of various sizes. The equivalent embedment length for allowable stress design ($l_e = 11.25d_b$) is based on an allowable stress of 7,500 psi (51.7 MPa), the accepted permissible value in masonry design (ref. 10). To achieve this capacity, the hook itself must be embedded a sufficient amount to prevent breakout/pullout. It is recommended that a minimum of 2$^1/_2$ in. (630 mm) embedment over the hook be provided (ref. 8), unless a more detailed analysis is performed.

A combination of hook and development length must be used when the equivalent embedment length of the hook, l_e, is less than the required minimum development length, l_d. In this case, development length equal to (l_d - l_e) must be provided in addition to the hook. This additional development length is measured from the start of the hook (point of tangency with the main portion of the bar).

JOINT REINFORCEMENT SPLICES

While not currently addressed by the MSJC or IBC, wire and joint reinforcement is typically spliced 6 in. (152 mm) minimum to transfer shrinkage stresses. Slippage of the deformed side wires is resisted by surface bond as well as by mechanical anchorage of the embedded portions of the cross wires.

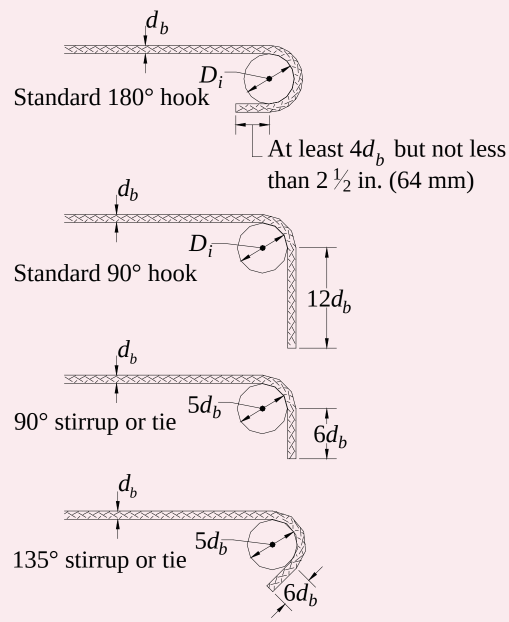

Figure 1—Standard Hooks

Table 8—Standard Hooks—Dimensions and Equivalent Embedment Lengths

Bar size no.	Bar diameter d_b, in. (mm)	Minimum inside diameter of bend[A] D_i, in. (mm)	180° hook, $4d_b$ extension in. (mm)	135° hook, $6d_b$ extension in. (mm)	90° hook, $12d_b$ extension in. (mm)	Equivalent embedment length l_e, in. (mm) for: Allowable stress design, $l_e = 11.25d_b$	Strength design $l_e = 13d_b$
3 (M#10)	0.375 (9.5)	2.3 (57)	2.5[B] (64)	4.0[C] (102)	4.5 (114)	4.2 (107)	4.8 (122)
4 (M#13)	0.500 (13)	3.0 (76)	2.5[B] (64)	4.0[C] (102)	6.0 (152)	5.6 (143)	6.5 (165)
5 (M#16)	0.625 (16)	3.8 (95)	2.5 (64)	4.0[C] (102)	7.5 (191)	7.0 (178)	8.1 (206)
6 (M#19)	0.750 (19)	4.5 (114)	3.0 (76)	4.5 (114)	9.0 (229)	8.4 (214)	9.7 (246)
7 (M#22)	0.875 (22)	5.3 (133)	3.5 (89)	5.3 (133)	10.5 (267)	9.8 (250)	11.3 (287)
8 (M#25)	1.000 (25)	6.0 (152)	4.0 (102)	6.0 (152)	12.0 (305)	11.2 (286)	13.0 (330)
9 (M#29)	1.128 (29)	9.0 (229)	4.5 (115)	6.8 (172)	13.5 (343)	12.6 (322)	14.6 (371)
10 (M#32)	1.270 (32)	10.2 (259)	5.1 (130)	7.6 (193)	15.2 (386)	14.3 (363)	NP[D]
11 (M#36)	1.410 (36)	11.3 (287)	5.6 (142)	8.5 (216)	16.9 (429)	15.9 (404)	NP[D]

[A] Based on Grade 60 reinforcing bars as follows: D_i must equal or exceed $6d_b$ for bar sizes No. 3 through 8 (M#10–M#25); $8d_b$ for No. 9–11 (M #29–M#36) bars. Diameters of bend may be decreased to $5d_b$ for Grade 40, No. 3–7 (M#10–M#22).
[B] For 180° standard hooks, bar extensions may not be less than 2$^1/_2$ in. (64 mm).
[C] For 135° standard hooks, bar extensions may not be less than 4 in. (102 mm).
[D] Maximum reinforcing bar size for strength design is No. 9 (M#29)

NOTATIONS:

D_i = min. inside diameter of bend for standard hooks, in. (mm)
d_b = nominal diameter of reinforcement, in. (mm)
K = the least of the masonry cover, $5d_b$ and the clear spacing between adjacent reinforcement, in. (mm)
F_s = allowable tensile stress in reinforcement, psi (MPa)
f'_m = specified compressive strength of masonry, psi (MPa)
f_s = calculated tensile or compressive stress in steel, psi (MPa)
f_y = specified yield strength of steel, psi (MPa)
l_d = embedment length or lap splice length of straight reinforcement, in. (mm)
l_e = equivalent embedment length provided by standard hooks measured from the start of the hook (point of tangency), in. (mm)
γ = reinforcement size factor
ϕ = strength reduction factor

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