

**Table 3.9.3** Minimum Beam Width (inches) To Satisfy 2 Bar Diameters Clear Spacing

BAR SIZE	NUMBER OF BARS IN SINGLE LAYER						
	2	3	4	5	6	7	8
#4	6.8	8.3	9.8	11.3	12.8	14.3	15.8
#5	7.1	9.0	10.9	12.8	14.6	16.5	18.4
#6	7.5	9.8	12.0	14.3	16.5	18.8	21.0
#7	7.9	10.5	13.1	15.8	18.4	21.0	23.6
#8	8.3	11.3	14.3	17.3	20.3	23.3	26.3
#9	8.6	12.0	15.4	18.8	22.2	25.6	28.9
#10	9.1	12.9	16.7	20.5	24.3	28.1	31.9
#11	9.5	13.7	17.9	22.2	26.4	30.6	34.9
#14	12.2	15.9	20.9	26.0	31.1	36.2	41.2
#18	15.0	19.8	26.6	33.3	40.1	46.9	53.7

Table Assumptions:

- Side cover 1.5 in. each side.
- #3 stirrups for bars #11 and smaller.
- #4 stirrups for bars #14 and #18.
- Since stirrups are bent around 4 stirrup bar diameters, the distance from centroid of bar nearest side face of beam to inside face of #3 stirrup is taken as 0.75 in. for bars #11 and smaller; and equal to the bar radius for #14 and #18 bars.

**Table 3.9.4** Minimum Beam Width (inches) To Satisfy 3 Bar Diameters Clear Spacing

BAR SIZE	NUMBER OF BARS IN SINGLE LAYER						
	2	3	4	5	6	7	8
#4	7.3	9.3	11.3	13.3	15.3	17.3	19.3
#5	7.8	10.3	12.8	15.3	17.8	20.3	22.8
#6	8.3	11.3	14.3	17.3	20.3	23.3	26.3
#7	8.8	12.3	15.8	19.3	22.8	26.3	29.8
#8	9.3	13.3	17.3	21.3	25.3	29.3	33.3
#9	9.8	14.3	18.8	23.3	27.8	32.3	36.8
#10	10.3	15.4	20.5	25.6	30.7	35.7	40.8
#11	10.9	16.5	22.2	27.8	33.5	39.1	44.7
#14	12.5	19.2	26.0	32.8	39.6	46.3	53.1
#18	15.3	24.3	33.3	42.4	51.4	60.4	69.5

Table Assumptions:

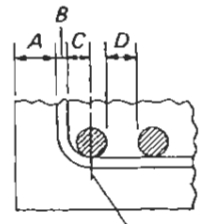
- Side cover 1.5 in. each side.
- #3 stirrups for bars #11 and smaller.
- #4 stirrups for bars #14 and #18.
- Since stirrups are bent around 4 stirrup bar diameters, the distance from centroid of bar nearest side face of beam to inside face of #3 stirrup is taken as 0.75 in. for bars #11 and smaller; and equal to the bar radius for #14 and #18 bars.

$A = 1\frac{1}{2}$  in. clear cover to stirrup

$B = \frac{3}{8}$  in. stirrup bar diameter

$C =$  For #11 and smaller bars, use twice the diameter of #3 stirrups (i.e.,  $C = 0.75$  in.). For #14 and #18 bars, use  $C = 0.5d_b$

$D =$  clear distance between bars =  $d_b$  or 1 in., whichever is greater (where  $d_b$  is the diameter of the larger adjacent longitudinal bar)



Diameter of corner bar assumed to be located intersect the horizontal tangent to stirrup bend

**Table 3.9.2** Minimum Beam Width (inches) According to the ACI Code\*

SIZE OF BARS	NUMBER OF BARS IN SINGLE LAYER OF REINFORCEMENT								ADD FOR EACH ADDED BAR
	2	3	4	5	6	7	8		
#4	6.8	8.3	9.8	11.3	12.8	14.3	15.8	1.50	
#5	6.9	8.5	10.2	11.8	13.4	15.0	16.7	1.63	
#6	7.0	8.8	10.5	12.3	14.0	15.8	17.5	1.75	
#7	7.2	9.0	10.9	12.8	14.7	16.5	18.4	1.88	
#8	7.3	9.3	11.3	13.3	15.3	17.3	19.3	2.00	
#9	7.6	9.8	12.2	14.3	16.6	18.8	21.1	2.26	
#10	7.8	10.4	12.9	15.5	18.0	20.5	23.1	2.54	
#11	8.1	10.9	13.8	16.6	19.4	22.2	25.0	2.82	
#14	8.9	12.3	15.7	19.1	22.5	25.9	29.3	3.40	
#18	10.6	15.1	19.6	24.1	28.6	33.1	37.6	4.51	

\*Table shows minimum beam widths when #3 stirrups are used.  
 If additional bars, add dimension in last column for each added bar.  
 If bars of different sizes, determine from table the beam width for smaller size bars and add last column figure for each larger bar used.

Assumes maximum aggregate size does not exceed three-fourths of the clear space between bars (ACI-3.3.2). Table computation procedure is in agreement with the ACI Code interpretation of ACI Committee 310, as used in the *Strength Design Handbook* [2.20].

**Table 3.9.1** Total Areas for Various Numbers of Reinforcing Bars

BAR SIZE	NOMINAL DIAMETER (in.)	WEIGHT (lb/ft)	NUMBER OF BARS									
			1	2	3	4	5	6	7	8	9	10
#3	0.375	0.376	0.11	0.22	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10
#4	0.500	0.668	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
#5	0.625	1.043	0.31	0.62	0.93	1.24	1.55	1.86	2.17	2.48	2.79	3.10
#6	0.750	1.502	0.44	0.88	1.32	1.76	2.20	2.64	3.08	3.52	4.40	4.40
#7	0.875	2.044	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00
#8	1.000	2.670	0.79	1.58	2.37	3.16	3.95	4.74	5.53	6.32	7.11	7.90
#9	1.128	3.400	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
#10	1.270	4.303	1.27	2.54	3.81	5.08	6.35	7.62	8.89	10.16	11.43	12.70
#11	1.410	5.313	1.56	3.12	4.68	6.24	7.80	9.36	10.92	12.48	14.04	15.60
#14*	1.693	7.65	2.25	4.50	6.75	9.00	11.25	13.50	15.75	18.00	20.25	22.50
#18*	2.257	13.60	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00	40.00

\*#14 and #18 bars are used primarily as column reinforcement and are rarely used in beams.

**REINFORCING BARS — SIZE DESIGNATIONS AND NOMINAL DIMENSIONS**

BAR SIZE DESIGNATION	NOMINAL DIMENSIONS		
	DIAMETER (in.)	AREA (in. <sup>2</sup> )	WEIGHT (lb/ft)
#10 [#3]	0.375	0.11	0.376
#13 [#4]	0.500	0.20	0.668
#16 [#5]	0.625	0.31	1.043
#19 [#6]	0.750	0.44	1.502
#22 [#7]	0.875	0.60	2.044
#25 [#8]	1.000	0.79	2.670
#29 [#9]	1.128	1.00	3.400
#32 [#10]	1.270	1.27	4.303
#36 [#11]	1.410	1.56	5.313
#43 [#14]	1.693	2.25	7.65
#57 [#18]	2.257	4.00	13.60

**Notice**

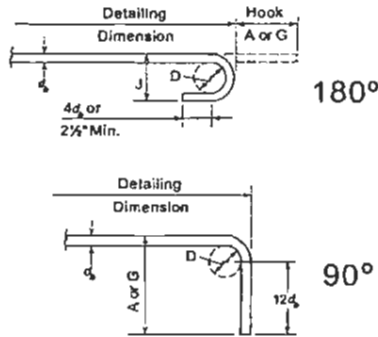
Nearly all reinforcing bars currently produced in the USA are marked with the numbers 10, 13, 16, etc., to designate bar sizes. These bar size numbers correspond to the designations 3, 4, 5, etc., as shown in the accompanying table.

To follow current industry practice, only the bar size designations #10, #13, #16, etc., are shown in the following figures and tables. More information on bar markings is presented in CRSI's *Manual of Standard Practice*.

**Notes**

1. ASTM A615 Grade 40 is limited to bar sizes #10 through #19.
2. Check availability with local suppliers for bar sizes #43 and #57.

**DETAILS OF STANDARD HOOKS**

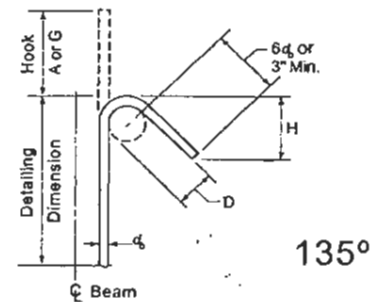
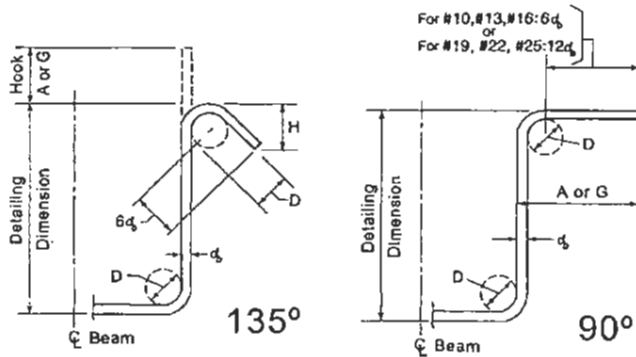


**RECOMMENDED END HOOKS, ALL GRADES OF STEEL**

BAR SIZE	D	180° HOOKS		90° HOOKS
		A or G	J	A or G
#10	2 1/4"	5"	3"	6"
#13	3"	6"	4"	8"
#16	3 3/4"	7"	5"	10"
#19	4 1/2"	8"	6"	1'-0"
#22	5 1/4"	10"	7"	1'-2"
#25	6"	11"	8"	1'-4"
#29	9 1/2"	1'-3"	11 1/4"	1'-7"
#32	10 1/4"	1'-5"	1'-1 1/4"	1'-10"
#36	12"	1'-7"	1'-2 1/2"	2'-0"
#43	18 1/4"	2'-3"	1'-9 1/4"	2'-7"
#57	24"	3'-0"	2'-4 1/2"	3'-5"

**ALL GRADES OF STEEL**

- D = Finished inside bend diameter
- $d_b$  = Nominal bar diameter
- Min. D =  $6d_b$  for #10 through #25
- =  $8d_b$  for #29, #32 and #36
- =  $10d_b$  for #43 and #57



**STIRRUP HOOKS (Tie Hooks Similar)**

BAR SIZE	D	90°		135°	
		A or G	A or G	A or G	H*
#10	1 1/2"	4"	4"	2 1/2"	
#13	2"	4 1/2"	4 1/2"	3"	
#16	2 1/2"	6"	5 1/2"	3 3/4"	
#19	4 1/2"	1'-0"	8"	4 1/2"	
#22	5 1/4"	1'-2"	9"	5 1/4"	
#25	6"	1'-4"	10 1/4"	6"	

\*H dimension is approximate.

**SEISMIC STIRRUP / TIE HOOKS**

BAR SIZE	135° SEISMIC HOOK		
	D	A or G	H*
#10	1 1/2"	4 1/2"	3"
#13	2"	4 1/2"	3"
#16	2 1/2"	5 1/2"	3 3/4"
#19	4 1/2"	8"	4 1/2"
#22	5 1/4"	9"	5 1/4"
#25	6"	10 1/4"	6"

\*H dimension is approximate.

# DESIGN AND DETAILING DATA — ACI

4/5

ACI Tension Lap Splice Lengths for  $f'_c = 3,000, 4,000$  and  $5,000$  psi

Bar Size	Lap Class	$f'_c = 3,000$ psi				$f'_c = 4,000$ psi				$f'_c = 5,000$ psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#10	A	22	32	17	25	19	28	15	22	17	25	13	19
	B	28	42	22	32	24	36	19	28	22	33	17	25
#13	A	29	43	22	33	25	37	19	29	22	33	17	26
	B	37	56	29	43	32	48	25	37	29	43	22	33
#16	A	36	54	28	41	31	47	24	36	28	42	22	32
	B	47	70	36	54	40	60	31	47	36	54	28	42
#19	A	43	64	33	50	37	56	29	43	33	50	26	38
	B	56	84	43	64	48	72	37	56	43	65	33	50
#22	A	63	94	48	72	54	81	42	63	49	73	37	56
	B	81	122	63	94	70	106	54	81	63	94	49	73
#25	A	72	107	55	82	62	93	48	71	55	83	43	64
	B	93	139	72	107	80	121	62	93	72	108	55	83
#29	A	81	121	62	93	70	105	54	81	63	94	48	72
	B	105	157	81	121	91	136	70	105	81	122	63	94
#32	A	91	136	70	105	79	118	61	91	70	105	54	81
	B	118	177	91	136	102	153	79	118	91	137	70	105
#36	A	101	151	78	116	87	131	67	101	78	117	60	90
	B	131	196	101	151	113	170	87	131	101	152	78	117
#43	N/A	121	181	93	139	105	157	81	121	94	140	72	108
#57	N/A	161	241	124	186	139	209	107	161	125	187	96	144

ACI Tension Lap Splice Lengths for  $f'_c = 6,000, 7,000$  and  $8,000$  psi

Bar Size	Lap Class	$f'_c = 6,000$ psi				$f'_c = 7,000$ psi				$f'_c = 8,000$ psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#10	A	15	23	12	18	14	21	12	16	13	20	12	15
	B	20	30	16	23	18	28	16	21	17	26	16	20
#13	A	20	31	16	24	19	28	15	22	18	26	14	20
	B	26	40	20	31	25	37	19	28	23	34	18	26
#16	A	25	38	20	29	24	35	18	27	22	33	17	25
	B	33	49	25	38	31	46	24	35	29	43	22	33
#19	A	31	46	24	35	28	42	22	33	26	40	20	30
	B	40	59	31	46	37	55	28	42	34	51	26	40
#22	A	44	66	34	51	41	61	32	47	38	58	30	44
	B	58	86	44	66	53	80	41	61	50	75	38	58
#25	A	51	76	39	58	47	70	36	54	44	66	34	51
	B	66	98	51	76	61	91	47	70	57	85	44	66
#29	A	57	85	44	66	53	79	41	61	49	74	38	57
	B	74	111	57	85	69	103	53	79	64	96	49	74
#32	A	64	96	49	74	59	89	46	69	56	83	43	64
	B	83	125	64	96	77	116	59	89	72	108	56	83
#36	A	71	107	55	82	66	99	51	76	62	93	48	71
	B	93	139	71	107	86	128	66	99	80	120	62	93
#43	N/A	86	128	66	99	79	119	61	91	74	111	57	85
#57	N/A	114	171	88	131	106	158	81	122	99	148	76	114

## TES

Tabulated values are based on Grade 60 reinforcing bars and normal-weight concrete.

Tension development lengths and tension lap splice lengths are based on ACI 318-02, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements. Lengths are in inches.

Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns	Case 1	Cover at least $1d_b$ and c.-c. spacing at least $2d_b$
	Case 2	Cover less than $1d_b$ or c.-c. spacing less than $2d_b$
All Others	Case 1	Cover at least $1d_b$ and c.-c. spacing at least $3d_b$
	Case 2	Cover less than $1d_b$ or c.-c. spacing less than $3d_b$

Lap Class A values are the required tension development lengths,  $l_d$ ; lap splice lengths are multiples of tension development lengths; Class A =  $1.0l_d$  and Class B =  $1.3l_d$  (ACI 318-02, Section 12.15.1).

Lap splices of #43 or #57 bars are not permitted. The tabulated values for those bar sizes are the tension development lengths.

bars are horizontal bars with more than 12 inches of concrete cast below the bars.

lightweight aggregate concrete, multiply the tabulated values by 1.3; or when  $f_{ct}$  is specified, the factor is  $6.7 \sqrt{f'_c/f_{ct}} \geq 1.0$ .

For epoxy-coated bars, multiply the tabulated values by one of the following factors:

Concrete Cover and Spacing	Top Bars	Other Bars
Cover $< 3d_b$ or c.-c. spacing $< 7d_b$	$1.7/1.3 = 1.31$	1.50
Cover $\geq 3d_b$ and c.-c. spacing $\geq 7d_b$	1.20	1.20

ACI Hook Development Lengths for  $f'_c = 3,000$  to  $8,000$  psi

Bar Size	$f'_c = 3,000$ psi	$f'_c = 4,000$ psi	$f'_c = 5,000$ psi	$f'_c = 6,000$ psi	$f'_c = 7,000$ psi	$f'_c = 8,000$ psi
#10	9	7	7	6	6	6
#13	11	10	9	8	7	7
#16	14	12	11	10	9	9
#19	17	15	13	12	11	10
#22	19	17	15	14	13	12
#25	22	19	17	16	15	14
#29	25	22	19	18	16	15
#32	28	24	22	20	19	17
#36	31	27	24	22	21	19
#43	37	32	29	27	25	23
#57	50	43	39	35	33	31

NOTES

1. Tabulated values are based on Grade 60 reinforcing bars and normal-weight concrete.
2. Tension development lengths of standard hooks are based on ACI 318-02, Section 12.5. Lengths are in inches.
3. For bar sizes #10 through #36 only:
  - a. If concrete cover conforms to ACI 318-02, Section 12.5.3(a), then a modification factor of 0.7 may be applied but the resulting length must not be less than  $8d_b$  nor 6 in.
  - b. If hook is enclosed in ties or stirrups conforming to ACI 318-02, Section 12.5.3(b), then a modification factor of 0.8 may be applied but the resulting length must not be less than  $8d_b$  nor 6 in.
4. For epoxy-coated hooks, multiply the tabulated values by 1.2.

ACI Compression Development and Lap Splice Lengths for  $f'_c = 3,000$  to  $8,000$  psi

Bar Size	Compression Development Lengths per $f'_c$						Compression Lap Splice Length
	$f'_c = 3,000$ psi	$f'_c = 4,000$ psi	$f'_c = 5,000$ psi	$f'_c = 6,000$ psi	$f'_c = 7,000$ psi	$f'_c = 8,000$ psi	
#10	9	8	8	8	8	8	12
#13	11	10	9	9	9	9	15
#16	14	12	12	12	12	12	19
#19	17	15	14	14	14	14	23
#22	19	17	16	16	16	16	27
#25	22	19	18	18	18	18	30
#29	25	22	21	21	21	21	34
#32	28	24	23	23	23	23	38
#36	31	27	26	26	28	26	43
#43	37	32	31	31	31	31	N/A
#57	50	43	41	41	41	41	N/A

NOTES

1. Tabulated values are based on Grade 60 reinforcing bars and normal-weight concrete.
2. Compression development lengths and compression lap splice lengths are based on ACI 318-02, Sections 12.3 and 12.16, respectively. Lengths are in inches.
3. For compression development lengths, if bars are enclosed in spirals or ties conforming to ACI 318-02, Section 12.3.3(b), then a modification factor of 0.75 may be applied but the resulting length must not be less than 8 in.
4. For compression lap splice lengths:
  - a. If bars are enclosed in a tied-reinforced compression member conforming to ACI 318-02, Section 12.17.2.4, then a modification factor of 0.83 may be applied but the resulting length must not be less than 12 in.
  - b. If bars are enclosed in a spirally-reinforced compression member conforming to ACI 318-02, Section 12.17.2.5, then a modification factor of 0.75 may be applied but the resulting length must not be less than 12 in.
  - c. The tabulated lengths are applicable for all concrete strengths of at least 3,000 psi.
5. ACI 318-02 does not allow lap splices of #43 and #57 bars, except to #36 and smaller bars.



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