

## Revisions to the SCDOT Bridge Design Manual

### Reinforcing Tension Development Lengths, and Splice Lengths Revised per AASHTO LRFD Bridge Design Specifications 8<sup>th</sup> Edition, November 2017

Due to changed reinforcing steel development and splice lengths required by updates to AASHTO LRFD Bridge Design Specifications, the Bridge Design Manual Figure 15.3-4 – Development Lengths For Straight Bars In Tension (4 ksi), Figure 15.3-5 – Development Lengths For Hooked Bars In Tension (4 ksi), and Figure 15.3-6 – Splice Lengths For Bars In Tension (4 ksi) shall be superseded by the Tables included in this Design Memorandum:

- Table 1: Straight Bar Development Length,  $\ell_d$  [in], for Horizontal Bars with  $> 12$ " Concrete Cast Below;  $f_c = 4$  ksi.;  $f_y = 60$  ksi.
- Table 2: Straight Bar Development Length,  $\ell_d$  [in], for Horizontal Bars with  $\leq 12$ " Concrete Cast Below, or Other Bars;  $f_c = 4$  ksi.;  $f_y = 60$  ksi.
- Table 3: Tension Lap Splice Length,  $\ell_{st}$  [in], for Horizontal Bars with  $> 12$ " Concrete Cast Below;  $f_c = 4$  ksi.;  $f_y = 60$  ksi.
- Table 4: Tension Lap Splice Length,  $\ell_{st}$  [in], for Horizontal Bars with  $\leq 12$ " Concrete Cast Below, or Other Bars;  $f_c = 4$  ksi.;  $f_y = 60$  ksi.
- Table 5: Hooked Bar Development Length,  $\ell_{dh}$  [in];  $f_c = 4$  ksi.;  $f_y = 60$  ksi.
- Note:

Tables include modification factors for reinforcement location, normal weight concrete, and reinforcement confinement as specified in AASHTO Articles 5.10.8.2.1b and 5.10.8.2.1c. Reinforcement confinement is conservatively calculated by taking transverse reinforcement index as 0. Excess reinforcement factor is taken conservatively as 1.0. Tension lap splice lengths are based on AASHTO Article 5.10.8.4. Tension hook development lengths are based on AASHTO Article 5.10.8.2.4. Concrete cover is defined as the cover to the bar being considered. For concrete cover or bar spacing that falls between table values, conservatively use lap splice shown in the table for smaller concrete cover or bar spacing, or calculate more precise length using AASHTO Article 5.10.8.2 for guidance. Bundled bars are based on AASHTO Article 5.10.8.2.3 and SCDOT BDM 15.3.1.8.

SCDOT BDM 15.3.1.7.2: For tension splices, the length of a lap splice,  $\ell_{st}$ , between bars of different sizes shall be governed by the smaller bar.

**Table 1: Straight Bar Development Length,  $\ell_d$  [in], for Horizontal Bars with > 12" Concrete Cast Below;  $f'_c = 4$  ksi.;  $f_y = 60$  ksi.**

Clear Cover	Bar Size US [M]	Reinforcement Spacing										
		4"	4 ½"	5"	5 ½"	6"	6 ½"	7"	7 ½"	8"	8 ½"	≥ 9"
1"	#3 [10]	15	15	15	15	15	15	15	15	15	15	15
	#4 [13]	19	19	19	19	19	19	19	19	19	19	19
	#5 [16]	28	28	28	28	28	28	28	28	28	28	28
	#6 [19]	39	39	39	39	39	39	39	39	39	39	39
	#7 [22]	50	50	50	50	50	50	50	50	50	50	50
	#8 [25]	63	63	63	63	63	63	63	63	63	63	63
	#9 [29]	77	77	77	77	77	77	77	77	77	77	77
	#10 [32]	93	93	93	93	93	93	93	93	93	93	93
	#11 [36]	110	110	110	110	110	110	110	110	110	110	110
	#14 [43]	N/A	146	146	146	146	146	146	146	146	146	146
#18 [57]	N/A	N/A	N/A	N/A	212	212	212	212	212	212	212	
1 ½"	#3 [10]	15	15	15	15	15	15	15	15	15	15	15
	#4 [13]	19	19	19	19	19	19	19	19	19	19	19
	#5 [16]	24	24	24	24	24	24	24	24	24	24	24
	#6 [19]	29	29	29	29	29	29	29	29	29	29	29
	#7 [22]	37	37	37	37	37	37	37	37	37	37	37
	#8 [25]	47	47	47	47	47	47	47	47	47	47	47
	#9 [29]	60	58	58	58	58	58	58	58	58	58	58
	#10 [32]	76	71	71	71	71	71	71	71	71	71	71
	#11 [36]	94	85	85	85	85	85	85	85	85	85	85
	#14 [43]	N/A	120	115	115	115	115	115	115	115	115	115
#18 [57]	N/A	N/A	N/A	N/A	182	182	182	182	182	182	182	
2"	#3 [10]	15	15	15	15	15	15	15	15	15	15	15
	#4 [13]	19	19	19	19	19	19	19	19	19	19	19
	#5 [16]	24	24	24	24	24	24	24	24	24	24	24
	#6 [19]	29	29	29	29	29	29	29	29	29	29	29
	#7 [22]	36	33	33	33	33	33	33	33	33	33	33
	#8 [25]	47	42	38	38	38	38	38	38	38	38	38
	#9 [29]	60	53	48	47	47	47	47	47	47	47	47
	#10 [32]	76	68	61	58	58	58	58	58	58	58	58
	#11 [36]	94	83	75	69	69	69	69	69	69	69	69
	#14 [43]	N/A	120	108	98	95	95	95	95	95	95	95
#18 [57]	N/A	N/A	N/A	N/A	159	153	153	153	153	153	153	
2 ½"	#3 [10]	15	15	15	15	15	15	15	15	15	15	15
	#4 [13]	19	19	19	19	19	19	19	19	19	19	19
	#5 [16]	24	24	24	24	24	24	24	24	24	24	24
	#6 [19]	29	29	29	29	29	29	29	29	29	29	29
	#7 [22]	36	33	33	33	33	33	33	33	33	33	33
	#8 [25]	47	42	38	38	38	38	38	38	38	38	38
	#9 [29]	60	53	48	44	43	43	43	43	43	43	43
	#10 [32]	76	68	61	55	51	49	49	49	49	49	49
	#11 [36]	94	83	75	68	63	59	59	59	59	59	59
	#14 [43]	N/A	120	108	98	90	83	81	81	81	81	81
#18 [57]	N/A	N/A	N/A	N/A	159	147	137	132	132	132	132	
≥ 3"	#3 [10]	15	15	15	15	15	15	15	15	15	15	15
	#4 [13]	19	19	19	19	19	19	19	19	19	19	19
	#5 [16]	24	24	24	24	24	24	24	24	24	24	24
	#6 [19]	29	29	29	29	29	29	29	29	29	29	29
	#7 [22]	36	33	33	33	33	33	33	33	33	33	33
	#8 [25]	47	42	38	38	38	38	38	38	38	38	38
	#9 [29]	60	53	48	44	43	43	43	43	43	43	43
	#10 [32]	76	68	61	55	51	48	48	48	48	48	48
	#11 [36]	94	83	75	68	63	58	54	53	53	53	53
	#14 [43]	N/A	120	108	98	90	83	77	72	70	70	70
#18 [57]	N/A	N/A	N/A	N/A	159	147	137	128	120	116	116	

**Table 2- Straight Bar Development Length  $\ell_d$  [in] for Horizontal Bars with  $\leq 12"$  Concrete Cast Below or Other Bars:  $f'_c = 4$  ksi  $\cdot f_y = 60$  ksi**

Clear Cover	Bar Size US [M]	Reinforcement Spacing										
		4"	4 ½"	5"	5 ½"	6"	6 ½"	7"	7 ½"	8"	8 ½"	≥ 9"
1"	#3 [10]	12	12	12	12	12	12	12	12	12	12	12
	#4 [13]	15	15	15	15	15	15	15	15	15	15	15
	#5 [16]	22	22	22	22	22	22	22	22	22	22	22
	#6 [19]	30	30	30	30	30	30	30	30	30	30	30
	#7 [22]	39	39	39	39	39	39	39	39	39	39	39
	#8 [25]	48	48	48	48	48	48	48	48	48	48	48
	#9 [29]	59	59	59	59	59	59	59	59	59	59	59
	#10 [32]	72	72	72	72	72	72	72	72	72	72	72
	#11 [36]	84	84	84	84	84	84	84	84	84	84	84
	#14 [43]	N/A	112	112	112	112	112	112	112	112	112	112
#18 [57]	N/A	N/A	N/A	N/A	163	163	163	163	163	163	163	
1 ½"	#3 [10]	12	12	12	12	12	12	12	12	12	12	12
	#4 [13]	15	15	15	15	15	15	15	15	15	15	15
	#5 [16]	18	18	18	18	18	18	18	18	18	18	18
	#6 [19]	22	22	22	22	22	22	22	22	22	22	22
	#7 [22]	29	29	29	29	29	29	29	29	29	29	29
	#8 [25]	36	36	36	36	36	36	36	36	36	36	36
	#9 [29]	46	45	45	45	45	45	45	45	45	45	45
	#10 [32]	59	55	55	55	55	55	55	55	55	55	55
	#11 [36]	72	65	65	65	65	65	65	65	65	65	65
	#14 [43]	N/A	92	88	88	88	88	88	88	88	88	88
#18 [57]	N/A	N/A	N/A	N/A	140	140	140	140	140	140	140	
2"	#3 [10]	12	12	12	12	12	12	12	12	12	12	12
	#4 [13]	15	15	15	15	15	15	15	15	15	15	15
	#5 [16]	18	18	18	18	18	18	18	18	18	18	18
	#6 [19]	22	22	22	22	22	22	22	22	22	22	22
	#7 [22]	28	26	26	26	26	26	26	26	26	26	26
	#8 [25]	36	32	29	29	29	29	29	29	29	29	29
	#9 [29]	46	41	37	36	36	36	36	36	36	36	36
	#10 [32]	59	52	47	45	45	45	45	45	45	45	45
	#11 [36]	72	64	58	53	53	53	53	53	53	53	53
	#14 [43]	N/A	92	83	76	73	73	73	73	73	73	73
#18 [57]	N/A	N/A	N/A	N/A	123	118	118	118	118	118	118	
2 ½"	#3 [10]	12	12	12	12	12	12	12	12	12	12	12
	#4 [13]	15	15	15	15	15	15	15	15	15	15	15
	#5 [16]	18	18	18	18	18	18	18	18	18	18	18
	#6 [19]	22	22	22	22	22	22	22	22	22	22	22
	#7 [22]	28	26	26	26	26	26	26	26	26	26	26
	#8 [25]	36	32	29	29	29	29	29	29	29	29	29
	#9 [29]	46	41	37	34	33	33	33	33	33	33	33
	#10 [32]	59	52	47	43	39	38	38	38	38	38	38
	#11 [36]	72	64	58	53	48	45	45	45	45	45	45
	#14 [43]	N/A	92	83	76	69	64	62	62	62	62	62
#18 [57]	N/A	N/A	N/A	N/A	123	113	105	102	102	102	102	
≥ 3"	#3 [10]	12	12	12	12	12	12	12	12	12	12	12
	#4 [13]	15	15	15	15	15	15	15	15	15	15	15
	#5 [16]	18	18	18	18	18	18	18	18	18	18	18
	#6 [19]	22	22	22	22	22	22	22	22	22	22	22
	#7 [22]	28	26	26	26	26	26	26	26	26	26	26
	#8 [25]	36	32	29	29	29	29	29	29	29	29	29
	#9 [29]	46	41	37	34	33	33	33	33	33	33	33
	#10 [32]	59	52	47	43	39	37	37	37	37	37	37
	#11 [36]	72	64	58	53	48	45	41	41	41	41	41
	#14 [43]	N/A	92	83	76	69	64	59	56	54	54	54
#18 [57]	N/A	N/A	N/A	N/A	123	113	105	98	92	89	89	

**Table 3: Tension Lap Splice Length,  $s_{st}$  [in] for Horizontal Bars with > 12" Concrete Cast Below;  $f'_c = 4$  ksi.;  $f_y = 60$  ksi.**

Clear Cover	Bar Size US [M]	Reinforcement Spacing																	
		4"		4 ½"		5"		5 ½"		6"		6 ½"		7"		7 ½"		≥ 8"	
		Class		Class		Class		Class		Class		Class		Class		Class		Class	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1"	#3 [10]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#4 [13]	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25
	#5 [16]	28	37	28	37	28	37	28	37	28	37	28	37	28	37	28	37	28	37
	#6 [19]	39	50	39	50	39	50	39	50	39	50	39	50	39	50	39	50	39	50
	#7 [22]	50	65	50	65	50	65	50	65	50	65	50	65	50	65	50	65	50	65
	#8 [25]	63	82	63	82	63	82	63	82	63	82	63	82	63	82	63	82	63	82
	#9 [29]	77	99	77	99	77	99	77	99	77	99	77	99	77	99	77	99	77	99
	#10 [32]	N/A	N/A	93	121	93	121	93	121	93	121	93	121	93	121	93	121	93	121
#11 [36]	N/A	N/A	N/A	N/A	110	142	110	142	110	142	110	142	110	142	110	142	110	142	
1 ½"	#3 [10]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#4 [13]	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25
	#5 [16]	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31
	#6 [19]	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37
	#7 [22]	37	49	37	49	37	49	37	49	37	49	37	49	37	49	37	49	37	49
	#8 [25]	47	61	47	61	47	61	47	61	47	61	47	61	47	61	47	61	47	61
	#9 [29]	60	78	58	76	58	76	58	76	58	76	58	76	58	76	58	76	58	76
	#10 [32]	N/A	N/A	71	92	71	92	71	92	71	92	71	92	71	92	71	92	71	92
#11 [36]	N/A	N/A	N/A	N/A	85	110	85	110	85	110	85	110	85	110	85	110	85	110	
2"	#3 [10]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#4 [13]	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25
	#5 [16]	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31
	#6 [19]	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37
	#7 [22]	36	47	33	43	33	43	33	43	33	43	33	43	33	43	33	43	33	43
	#8 [25]	47	61	42	55	38	49	38	49	38	49	38	49	38	49	38	49	38	49
	#9 [29]	60	78	53	69	48	62	47	61	47	61	47	61	47	61	47	61	47	61
	#10 [32]	N/A	N/A	68	88	61	79	58	75	58	75	58	75	58	75	58	75	58	75
#11 [36]	N/A	N/A	N/A	N/A	75	97	69	90	69	90	69	90	69	90	69	90	69	90	
2 ½"	#3 [10]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#4 [13]	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25
	#5 [16]	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31
	#6 [19]	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37
	#7 [22]	36	47	33	43	33	43	33	43	33	43	33	43	33	43	33	43	33	43
	#8 [25]	47	61	42	55	38	49	38	49	38	49	38	49	38	49	38	49	38	49
	#9 [29]	60	78	53	69	48	62	44	57	43	55	43	55	43	55	43	55	43	55
	#10 [32]	N/A	N/A	68	88	61	79	55	72	51	66	49	63	49	63	49	63	49	63
#11 [36]	N/A	N/A	N/A	N/A	75	97	68	88	63	81	59	76	59	76	59	76	59	76	
≥ 3"	#3 [10]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#4 [13]	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25	19	25
	#5 [16]	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31	24	31
	#6 [19]	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37
	#7 [22]	36	47	33	43	33	43	33	43	33	43	33	43	33	43	33	43	33	43
	#8 [25]	47	61	42	55	38	49	38	49	38	49	38	49	38	49	38	49	38	49
	#9 [29]	60	78	53	69	48	62	44	57	43	55	43	55	43	55	43	55	43	55
	#10 [32]	N/A	N/A	68	88	61	79	55	72	51	66	48	62	48	62	48	62	48	62
#11 [36]	N/A	N/A	N/A	N/A	75	97	68	88	63	81	58	75	54	70	53	69	53	69	

TENSION LAP SPLICES	Percent of $A_s$ spliced within required lap length	
$A_s$ , provided/ $A_s$ , required	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

$A_s$ , provided = Area of reinforcement provided and  $A_s$ , required = Area of reinforcement required by analysis

**Table 4: Tension Lap Splice Length,  $l_{st}$  [in] for Horizontal Bars with  $\leq 12"$  Concrete Cast Below, or Other Bars;  $f'_c = 4$  ksi.;  $f_y = 60$  ksi.**

Clear Cover	Bar Size US [M]	Reinforcement Spacing																	
		4"		4 ½"		5"		5 ½"		6"		6 ½"		7"		7 ½"		≥ 8"	
		Class		Class		Class		Class		Class		Class		Class		Class		Class	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1"	#3 [10]	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15
	#4 [13]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#5 [16]	22	28	22	28	22	28	22	28	22	28	22	28	22	28	22	28	22	28
	#6 [19]	30	39	30	39	30	39	30	39	30	39	30	39	30	39	30	39	30	39
	#7 [22]	39	50	39	50	39	50	39	50	39	50	39	50	39	50	39	50	39	50
	#8 [25]	48	63	48	63	48	63	48	63	48	63	48	63	48	63	48	63	48	63
	#9 [29]	59	77	59	77	59	77	59	77	59	77	59	77	59	77	59	77	59	77
	#10 [32]	N/A	N/A	72	93	72	93	72	93	72	93	72	93	72	93	72	93	72	93
#11 [36]	N/A	N/A	N/A	N/A	84	110	84	110	84	110	84	110	84	110	84	110	84	110	
1 ½"	#3 [10]	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15
	#4 [13]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#5 [16]	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24
	#6 [19]	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29
	#7 [22]	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37	29	37
	#8 [25]	36	47	36	47	36	47	36	47	36	47	36	47	36	47	36	47	36	47
	#9 [29]	46	60	45	58	45	58	45	58	45	58	45	58	45	58	45	58	45	58
	#10 [32]	N/A	N/A	55	71	55	71	55	71	55	71	55	71	55	71	55	71	55	71
#11 [36]	N/A	N/A	N/A	N/A	65	85	65	85	65	85	65	85	65	85	65	85	65	85	
2"	#3 [10]	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15
	#4 [13]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#5 [16]	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24
	#6 [19]	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29
	#7 [22]	28	36	26	33	26	33	26	33	26	33	26	33	26	33	26	33	26	33
	#8 [25]	36	47	32	42	29	38	29	38	29	38	29	38	29	38	29	38	29	38
	#9 [29]	46	60	41	53	37	48	36	47	36	47	36	47	36	47	36	47	36	47
	#10 [32]	N/A	N/A	52	68	47	61	45	58	45	58	45	58	45	58	45	58	45	58
#11 [36]	N/A	N/A	N/A	N/A	58	75	53	69	53	69	53	69	53	69	53	69	53	69	
2 ½"	#3 [10]	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15
	#4 [13]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#5 [16]	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24
	#6 [19]	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29
	#7 [22]	28	36	26	33	26	33	26	33	26	33	26	33	26	33	26	33	26	33
	#8 [25]	36	47	32	42	29	38	29	38	29	38	29	38	29	38	29	38	29	38
	#9 [29]	46	60	41	53	37	48	34	44	33	43	33	43	33	43	33	43	33	43
	#10 [32]	N/A	N/A	52	68	47	61	43	55	39	51	38	49	38	49	38	49	38	49
#11 [36]	N/A	N/A	N/A	N/A	58	75	53	68	48	63	45	59	45	59	45	59	45	59	
≥ 3"	#3 [10]	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15	12	15
	#4 [13]	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19	15	19
	#5 [16]	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24	18	24
	#6 [19]	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29	22	29
	#7 [22]	28	36	26	33	26	33	26	33	26	33	26	33	26	33	26	33	26	33
	#8 [25]	36	47	32	42	29	38	29	38	29	38	29	38	29	38	29	38	29	38
	#9 [29]	46	60	41	53	37	48	34	44	33	43	33	43	33	43	33	43	33	43
	#10 [32]	N/A	N/A	52	68	47	61	43	55	39	51	37	48	37	48	37	48	37	48
#11 [36]	N/A	N/A	N/A	N/A	58	75	53	68	48	63	45	58	41	54	41	53	41	53	

TENSION LAP SPLICES	Percent of $A_s$ spliced within required lap length	
$A_s$ , provided/ $A_s$ , required	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

$A_s$ , provided = Area of reinforcement provided and  $A_s$ , required = Area of reinforcement required by analysis

<b>Table 5: Hooked Bar Development Length, <math>\ell_{dh}</math> [in]; <math>f'_c = 4 \text{ ksi.}; f_y = 60 \text{ ksi.}</math></b>		
Bar Size US [M]	For hooks with side cover normal to the plane of the hook $\geq 2 \frac{1}{2}$ "	For hooks with side cover normal to the plane of the hook $< 2 \frac{1}{2}$ "
	AND For 90° hooks with cover on the bar extension beyond hook $\geq 2$ "	OR For 90° hooks with cover on the bar extension beyond hook $< 2$ "
#3 [10]	6	8
#4 [13]	8	10
#5 [16]	10	12
#6 [19]	12	15
#7 [22]	14	17
#8 [25]	16	19
#9 [29]	18	22
#10 [32]	20	25
#11 [36]	22	27
#14 [43]	33	33
#18 [57]	43	43