TABLE OF CONTENTS – REINFORCING STEEL

CHAPTER 7

* Indicates 11 x 17 sheet; all others are 8½ x 11.

INTRODUCTION

Chapter 7 of this manual establishes the practices and requirements regarding the use of reinforcing steel. Development lengths and lap splices in the tables provided in this chapter are intended to assist designer for design and detailing of concrete member.

Development length and lap splices shall be determined in accordance with AASHTO LRFD 7th Edition. For concrete with a specified compressive strength greater than 10 ksi, the development length and lap splices shall be calculated in accordance with 2015 AASHTO LRFD 7th Edition Interim or later revisions.

References to AASHTO LRFD specifications in the chapter refer to the current AASHTO LRFD Bridge Design Specifications and VDOT Modifications (IIM-S&B-80).

Several major changes to past practices are as follows:

1. Revised and reorganized the entire Section 7.02 based on AASHTO LRFD.

2. Removed content regarding epoxy-coated reinforcing steel as the VDOT discontinued the use of the epoxy coated bars and galvanized bars.

WEIGHT LBS PER FT.	NOMINAL DIAMETER INCHES	SIZE	NUMBER	NOMINAL CROSS SECTIONAL AREA SQ. IN.	NOMINAL PERIMETER
.167	.250	1/4	2	.05	.786
.376	.375	3/8	3	.11	1.178
.668	.500	1/2	4	.20	1.571
1.043	.625	5/8	5	.31	1.963
1.502	.750	3/4	6	.44	2.356
2.044	.875	7/8	7	.60	2.749
2.670	1.000	1	8	.79	3.142
3.400	1.128	1	9	1.00	3.544
4.303	1.270	1 1/8	10	1.27	3.990
5.313	1.410	1 1/4	11	1.56	4.430
7.650	1.692	1 1/2	14S	2.25	5.316
13.600	2.256	2	18S	4.00	7.088

Spacing	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	Spacing
2	0.30	0.66	1.20	1.86	2.64						2
2 1/4	0.27	0.59	1.07	1.65	2.35	3.20					2 1/4
2 1/2	0.24	0.53	0.96	1.49	2.11	2.88	3.79				2 1/2
2 3/4	0.22	0.48	0.87	1.35	1.92	2.62	3.45				2 3/4
3	0.20	0.44	0.80	1.24	1.76	2.40	3.16	4.00			3
3 1/4	0.18	0.41	0.74	1.14	1.62	2.22	2.92	3.69			3 1/4
3 1/2	0.17	0.38	0.69	1.06	1.51	2.06	2.71	3.43	4.36		3 1/2
3 3/4	0.16	0.35	0.64	0.99	1.41	1.92	2.53	3.20	4.06	4.99	3 3/4
4	0.15	0.33	0.60	0.93	1.32	1.80	2.37	3.00	3.81	4.68	4
4 1/4	0.14	0.31	0.56	0.88	1.24	1.69	2.23	2.82	3.59	4.40	4 1/4
4 1/2	0.13	0.29	0.53	0.83	1.17	1.60	2.11	2.67	3.39	4.16	4 1/2
4 3/4	0.13	0.28	0.51	0.78	1.11	1.52	2.00	2.53	3.21	3.94	4 3/4
5	0.12	0.26	0.48	0.74	1.06	1.44	1.90	2.40	3.05	3.74	5
5 1/4	0.11	0.25	0.48	0.71	1.01	1.37	1.81	2.29	2.90	3.57	5 1/4
5 1/2	0.11	0.24	0.44	0.68	0.96	1.31	1.72	2.18	2.77	3.40	5 1/2
5 3/4	0.10	0.23	0.42	0.65	0.92	1.25	1.65	2.09	2.65	3.26	5 3/4
6	0.10	0.22	0.40	0.62	0.88	1.20	1.58	2.00	2.54	3.12	6
6 1/2	0.09	0.20	0.37	0.57	0.81	1.11	1.46	1.85	2.35	2.88	6 1/2
7	0.09	0.19	0.34	0.53	0.75	1.03	1.35	1.71	2.18	2.67	7
7 1/2	0.08	0.18	0.32	0.50	0.70	0.96	1.26	1.60	2.03	2.50	7 1/2
8	0.08	0.17	0.30	0.47	0.66	0.90	1.19	1.50	1.91	2.34	8
8 1/2	0.07	0.16	0.28	0.44	0.62	0.85	1.12	1.41	1.79	2.20	8 1/2
9	0.07	0.15	0.27	0.41	0.59	0.80	1.05	1.33	1.69	2.08	9
9 1/2	0.06	0,14	0.25	0.39	0.56	0.76	1.00	1.26	1.60	1.97	9 1/2
10	0.06	0.13	0.24	0.37	0.53	0.72	0.95	1.20	1.52	1.87	10
10 1/2	0.06	0.13	0.23	0.35	0.50	0.69	0.90	1.14	1.45	1.78	10 1/2
11	0.05	0.12	0.22	0.34	0.48	0.65	0.86	1.09	1.39	1.70	11
11 1/2			0.21	0.32	0.46	0.63	0.82	1.04	1.33	1.63	11 1/2
12			0.20	0.31	0.44	0.60	0.79	1.00	1.27	1.56	12
13			0.18	0.29	0.41	0.55	0.73	0.92	1.17	1.44	13
14			0.17	0.27	0.38	0.51	0.68	0.86	1.09	1.34	14
15			0.16	0.25	0.35	0.48	0.63	0.80	1.02	1.25	15
16			0.15	0.23	0.33	0.45	0.59	0.75	0.95	1.17	16
17			0.14	0.22	0.31	0.42	0.56	0.71	0.90	1.10	17
18			0.13	0.21	0.29	0.40	0.53	0.67	0.85	1.04	18

Areas given in sq. in.

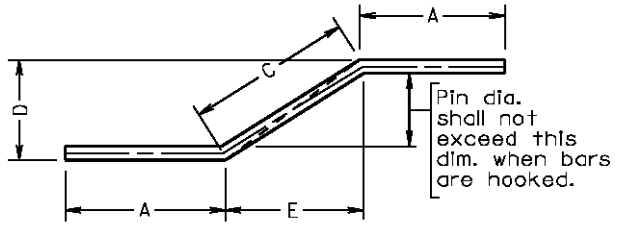
REINFORCING STEEL
REINFORCING STEEL PROPERTIES
AREA OF REBARS PER FOOT OF SECTION

REINFORCING STEEL

REINFORCING STEEL PROPERTIES

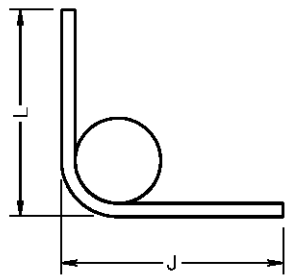
REINFORCING STEEL SCHEDULE AND BENDING DIAGRAM

Bar Size	Bar Dia.	Pin Dia.	Wt. lb/ft	TYPICAL DIMENSIONS							CORRECTIONS (K)			DEDUCTIONS FOR BENDS (K_1)				
				Slab Thk.	C	D	E	G	H	J	90° Hook	135° Hook	180° Hook	30°	45°	60°	75°	90°
3ga.	0.244	1 1/2	0.159					3 1/2		3 7/8	3 1/4		4 1/4	0.08	0.14	0.23	0.38	0.61
#3	0.375	2 1/4	0.376					4		6	5		5 1/8	0.12	0.21	0.36	0.58	0.94
#4	0.500	3	0.668					4 1/2		8	6 3/4		6	0.16	0.28	0.48	0.78	1.25
#4*	0.500	2	0.668						2 7/8	4 1/2	3 1/2	4 1/2		0.15	0.26	0.42	0.67	1.04
#5	0.625	3 3/4	1.043	7 1/2**	4 3/4	3 3/4	3 1/8	5		10	8 3/8		6 7/8	0.19	0.35	0.60	0.97	1.56
				8 **	5 1/2	4 1/4	3 5/8											
				8 1/2**	6 1/8	4 3/4	4 1/8											
				9 **	6 7/8	5 1/4	4 5/8											
#5*	0.625	2 1/2	1.043						3 5/8	5 5/8	4 3/8	5 1/2		0.19	0.33	0.53	0.83	1.30
#6	0.750	4 1/2	1.502					6		12	10 1/8		8 1/4	0.23	0.42	0.72	1.17	1.88
#6*	0.750	3 3/4	1.502						4 1/2	7 1/8	5 3/8	7 1/8		0.23	0.41	0.68	1.08	1.72
#7	0.875	5 1/4	2.044					7		14	11 3/4		9 5/8	0.27	0.49	0.83	1.36	2.19
#8	1.000	6	2.670					8		16	13 1/2		11	0.31	0.57	0.95	1.55	2.50
#9	1.128	9	3.400					10 1/8		19 1/4	15 7/8		14 7/8	0.37	0.69	1.20	2.01	3.31
#10	1.270	10	4.303					11 1/2		21 5/8	17 7/8		16 5/8	0.41	0.77	1.35	2.26	3.72
#11	1.410	11	5.313					12 3/4		24	19 7/8		18 1/2	0.46	0.86	1.50	2.51	4.13



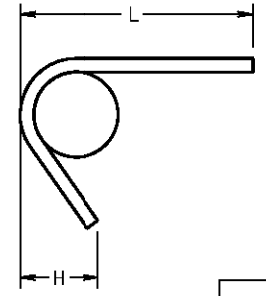
45° bent bars for slabs

Net Length = $\Sigma A + \Sigma C - K_1 \times$ No. of bends



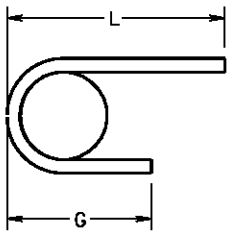
90° Hook

Net Length = L+K



135° Hook

Net Length = L+K



180° Hook

Net Length = L+K

Notes: To obtain Net Length of bar, subtract the deduction per bend from the summation of the distance from out-to-out of bar.
* Use this data for stirrups and tie bars only.
** When using VDOT's rebar mdl, manually calculate/correct slab bar length, weight and dimensions.

All dimensions are in inches.

Basic Development Lengths - Deformed Bars in Tension

Basic Development Length ℓ_{db} AASHTO 5.11.2.1						
			Reinforcement f_y = 60 ksi			
		Concrete f_c' =	3.0 ksi	4.0 ksi	5.0 ksi	6.0 ksi
Bar Size	Dia d_b	Area A_b	ℓ_{db}	ℓ_{db}	ℓ_{db}	ℓ_{db}
	in	in^2	in	in	in	in
3	0.375	0.11	9.0	9.0	9.0	9.0
4	0.500	0.20	12.0	12.0	12.0	12.0
5	0.625	0.31	15.0	15.0	15.0	15.0
6	0.750	0.44	19.1	18.0	18.0	18.0
7	0.875	0.60	26.0	22.5	21.0	21.0
8	1.000	0.79	34.2	29.6	26.5	24.2
9	1.128	1.00	43.3	37.5	33.5	30.6
10	1.270	1.27	55.0	47.6	42.6	38.9
11	1.410	1.56	67.5	58.5	52.3	47.8
14	1.692	2.25	93.5	81.0	72.4	66.1
18	2.256	4.00	121.2	105.0	93.9	85.7

Notes:

1. The basic tension development length ℓ_{db} in the table above is calculated based on AASHTO LRFD 5.11.2.1 for normal concrete and uncoated straight deformed reinforcement yield strength f_y = 60 ksi.

2. Tension development length ℓ_d shall be the product of the basic development length, ℓ_{db} in the table and the modification factor or factors (λ) specified in File No.07.02-12, but shall not be less than 12".

3. For design convenience, tables in File No. 07.02-2 provide the tension development length $\ell_d = \lambda * \ell_{db}$ based on bar spacing, clear cover and top bars for uncoated deformed reinforcement in normal weight concrete.

Development Lengths - Deformed Bars in Tension

Center to Center Spacing < 6" or Clear Cover < 3" , Reinforcement f_y = 60 ksi

Development Length $\ell_d = \lambda * \ell_{db}$								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-1"	1'-0"	1'-1"	1'-0"	1'-1"	1'-0"	1'-1"	1'-0"
4	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"
5	1'-9"	1'-3"	1'-9"	1'-3"	1'-9"	1'-3"	1'-9"	1'-3"
6	2'-3"	1'-8"	2'-2"	1'-6"	2'-2"	1'-6"	2'-2"	1'-6"
7	3'-1"	2'-2"	2'-8"	1'-11"	2'-6"	1'-9"	2'-6"	1'-9"
8	4'-0"	2'-11"	3'-6"	2'-6"	3'-2"	2'-3"	2'-10"	2'-1"
9	5'-1"	3'-8"	4'-5"	3'-2"	3'-11"	2'-10"	3'-7"	2'-7"
10	6'-5"	4'-7"	5'-7"	4'-0"	5'-0"	3'-7"	4'-7"	3'-3"
11	7'-11"	5'-8"	6'-10"	4'-11"	6'-2"	4'-5"	5'-7"	4'-0"
14	10'-11"	7'-10"	9'-6"	6'-9"	8'-6"	6'-1"	7'-9"	5'-7"
18	14'-2"	10'-2"	12'-3"	8'-9"	11'-0"	7'-10"	10'-0"	7'-2"

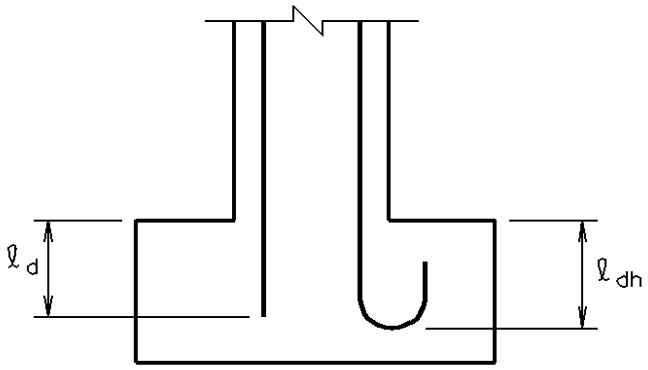
Center to Center Spacing ≥ 6" and Clear Cover ≥ 3", Reinforcement f_y = 60 ksi

Development Length $\ell_d = \lambda * \ell_{db}$								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"
4	1'-2"	1'-0"	1'-2"	1'-0"	1'-2"	1'-0"	1'-2"	1'-0"
5	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"
6	1'-10"	1'-4"	1'-9"	1'-3"	1'-9"	1'-3"	1'-9"	1'-3"
7	2'-6"	1'-9"	2'-2"	1'-6"	2'-0"	1'-5"	2'-0"	1'-5"
8	3'-3"	2'-4"	2'-10"	2'-0"	2'-6"	1'-10"	2'-4"	1'-8"
9	4'-1"	2'-11"	3'-6"	2'-6"	3'-2"	2'-3"	2'-11"	2'-1"
10	5'-2"	3'-8"	4'-6"	3'-3"	4'-0"	2'-11"	3'-8"	2'-8"
11	6'-4"	4'-7"	5'-6"	3'-11"	4'-11"	3'-6"	4'-6"	3'-3"
14	8'-9"	6'-3"	7'-7"	5'-5"	6'-10"	4'-10"	6'-3"	4'-5"
18	11'-4"	8'-1"	9'-10"	7'-0"	8'-10"	6'-4"	8'-0"	5'-9"

Development Lengths - Deformed Bars in Tension (cont'd.)

Notes:

1. Values for the development length ℓ_d in the tables are for normal weight concrete and reinforcement f_y = 60 ksi and have been rounded up to the next highest inch.
2. Top bars are horizontal bars with more than 12" fresh concrete cast below the bars.
3. The development length shall not be less than 12".
4. For bundled bars, development length ℓ_d shall be that for the individual bar increased by 20 percent for a three-bar bundle and by 33 percent for a four-bar bundle.
5. For modification factors, see File No. 07.02-12.



Development Length

Basic Development Lengths - Deformed Bars in Compression

Reinforcement f_y = 60 ksi

Basic Development Length ℓ_{db} AASHTO 5.11.2.2						
Concrete f_c' =			3.0 ksi	4.0 ksi	5.0 ksi	6.0 ksi
Bar Size	Dia d_b	Area A_b	ℓ_{db}	ℓ_{db}	ℓ_{db}	ℓ_{db}
	in	in^2	in	in	in	in
3	0.375	0.11	8.2	7.1	6.8	6.8
4	0.500	0.20	10.9	9.5	9.00	9.00
5	0.625	0.31	13.6	11.8	11.3	11.3
6	0.750	0.44	16.4	14.2	13.5	13.5
7	0.875	0.60	19.1	16.5	15.8	15.8
8	1.000	0.79	21.8	18.9	18.0	18.0
9	1.128	1.00	24.6	21.3	20.3	20.3
10	1.270	1.27	27.7	24.0	22.9	22.9
11	1.410	1.56	30.8	26.7	25.4	25.4
14	1.692	2.25	36.9	32.0	30.5	30.5
18	2.256	4.00	49.2	42.6	40.6	40.6

Notes:

1. The basic compression development length ℓ_{db} in the table is calculated based on AASHTO LRFD 5.11.2.2.1 for normal concrete and straight deformed reinforcement yield strength f_y = 60 ksi.
2. The development length ℓ_d, for deformed bars in compression shall be the product of the basic development length ℓ_{db} and applicable modification factors and shall not be less than 8".
3. For design convenience, the development length ℓ_d is provided in File No.07.02-5.

Development Lengths - Deformed Bars in Compression

Reinforcement f_y = 60 ksi

Development Length ℓ_d = modification factor(s) $*\ell_{db}$								
Concrete	**f_c' = 3.0 ksi**		**f_c' = 4.0 ksi**		**f_c' = 5.0 ksi**		**f_c' = 6.0 ksi**	
Bar Size	**Enclosed in Spiral**	**Others**	**Enclosed in Spiral**	**Others**	**Enclosed in Spiral**	**Others**	**Enclosed in Spiral**	**Others**
3	8”	9”	8”	8”	8”	8”	8”	8”
4	9”	11”	8”	10”	8”	9”	8”	9”
5	11”	1'-2”	9”	1'-0”	9”	1'-0”	9”	1'-0”
6	1'-1”	1'-5”	11”	1'-3”	11”	1'-2”	11”	1'-2”
7	1'-3”	1'-8”	1'-1”	1'-5”	1'-0”	1'-4”	1'-0”	1'-4”
8	1'-5”	1'-10”	1'-3”	1'-7”	1'-2”	1'-6”	1'-2”	1'-6”
9	1'-7”	2'-1”	1'-4”	1'-10”	1'-4”	1'-9”	1'-4”	1'-9”
10	1'-9”	2'-4”	1'-6”	2'-0”	1'-6”	1'-11”	1'-6”	1'-11”
11	2'-0”	2'-7”	1'-8”	2'-3”	1'-7”	2'-2”	1'-7”	2'-2”
14	2'-4”	3'-1”	2'-0”	2'-8”	1'-11”	2'-7”	1'-11”	2'-7”
18	3'-1”	4'-2”	2'-8”	3'-7”	2'-7”	3'-5”	2'-7”	3'-5”

Notes:

1. Values for the development length ℓ_d in the tables are for reinforcement f_y = 60 ksi and have been rounded up to the next highest inch.
2. If reinforcement is enclosed within a spiral composed of a bar of not less than 0.25” in diameter and spaced at not more than a 4” pitch, use the values in the column of Enclosed in Spiral, otherwise; use the development lengths in the Others column.
3. For bundled bars, development length ℓ_d shall be that for the individual bar increased by 20 percent for a three-bar bundle and by 33 percent for a four-bar bundle.
4. The development length shall not be less than 8”.
5. For modification factors, see File No. 07.02-13.

Development Lengths – Standard Hooked Bars in Tension

Reinforcement $f_y \leq 60$ ksi

	Basic Development Length ℓ_{hb} AASHTO 5.11.2.4			
Concrete	**f_c' = 3.0 ksi**	**f_c' = 4.0 ksi**	**f_c' = 5.0 ksi**	**f_c' = 6.0 ksi**
Bar Size	**in**	**in**	**in**	**in**
3	8.2	7.1	6.4	5.8
4	11.0	9.5	8.5	7.8
5	13.7	11.9	10.6	9.7
6	16.5	14.3	12.7	11.6
7	19.2	16.6	14.9	13.6
8	21.9	19.0	17.0	15.5
9	24.7	21.4	19.2	17.5
10	27.9	24.1	21.6	19.7
11	30.9	26.8	24.0	21.9
14	37.1	32.2	28.8	26.3
18	49.5	42.9	38.3	35.0

Notes:

1. Values in the table are the basic tension development lengths ℓ_{hb} for hooked bars with yield strength $f_y \leq 60.0$ ksi in normal weight concrete.
2. Development length ℓ_{dh} is the product of the basic development length ℓ_{hb} and the applicable modification factor(s).
3. Development length ℓ_{dh} shall not be less than 8.0*bar diameters and 6".
4. For modification factors, see File No. 07.02-13.

Lap Splices - Deformed Straight Bars in Tension

Lap splices ℓ_{sp} shall be calculated based on tension development length ℓ_d which should include all of the applicable modification factors specified in File No.07.02-12 or AASHTO LRFD Article 5.11.2.

The length of lap for tension lap splice shall not be less than 12" and the following for Class A, B or C splices according to AASHTO LRFD 5.11.5.3:

Class A Splice $1.0*\ell_d$

Class B Splice $1.3*\ell_d$

Class C Splice $1.7*\ell_d$

The classes of lap splice required for deformed bars in tension shall be as specified in the table below.

SPLICE CLASSIFICATIONS

Area of tensile reinforcement provided at splice location equal or more than twice that required for strength As-provided / As-required ≥ 2	Equal or less than 75 percent of bars lap spliced with required lap length	Class A Splice
	More than 75 percent of bars lap spliced with required lap length	Class B Splice
Area of tensile reinforcement provided at splice location less than twice that required for strength As-provided / As-required < 2	Equal or less than 50 percent of bars lap spliced with required lap length	Class B Splice
	More than 50 percent of bars lap spliced with required lap length	Class C Splice

For reinforcement in tension, lap splices shall not be allowed for bars larger than No. 11.

For lap splice within bundle and other situations, see AASHTO LRFD 5.11.5.

See File Nos. 7.02-8 thru 7.02-10 for lap splice length of bars in tension for reinforcement f_y = 60 ksi in normal weight concrete.

Lap Splices - Deformed Bars in Tension (cont'd)

Class A

Center to Center Spacing < 6" or Clear Cover < 3"								
ℓ_{sp} = 1.0 * Development Length ℓ_d								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-1"	1'-0"	1'-1"	1'-0"	1'-1"	1'-0"	1'-1"	1'-0"
4	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"
5	1'-9"	1'-3"	1'-9"	1'-3"	1'-9"	1'-3"	1'-9"	1'-3"
6	2'-3"	1'-8"	2'-2"	1'-6"	2'-2"	1'-6"	2'-2"	1'-6"
7	3'-1"	2'-2"	2'-8"	1'-11"	2'-6"	1'-9"	2'-6"	1'-9"
8	4'-0"	2'-11"	3'-6"	2'-6"	3'-2"	2'-3"	2'-10"	2'-1"
9	5'-1"	3'-8"	4'-5"	3'-2"	3'-11"	2'-10"	3'-7"	2'-7"
10	6'-5"	4'-7"	5'-7"	4'-0"	5'-0"	3'-7"	4'-7"	3'-3"
11	7'-11"	5'-8"	6'-10"	4'-11"	6'-2"	4'-5"	5'-7"	4'-0"
14	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							
18	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							

Class A

Center to Center Spacing ≥ 6" and Clear Cover ≥ 3"								
ℓ_{sp} = 1.0 * Development Length ℓ_d								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"
4	1'-2"	1'-0"	1'-2"	1'-0"	1'-2"	1'-0"	1'-2"	1'-0"
5	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"	1'-5"	1'-0"
6	1'-10"	1'-4"	1'-9"	1'-3"	1'-9"	1'-3"	1'-9"	1'-3"
7	2'-6"	1'-9"	2'-2"	1'-6"	2'-0"	1'-5"	2'-0"	1'-5"
8	3'-3"	2'-4"	2'-10"	2'-0"	2'-6"	1'-10"	2'-4"	1'-8"
9	4'-1"	2'-11"	3'-6"	2'-6"	3'-2"	2'-3"	2'-11"	2'-1"
10	5'-2"	3'-8"	4'-6"	3'-3"	4'-0"	2'-11"	3'-8"	2'-8"
11	6'-4"	4'-7"	5'-6"	3'-11"	4'-11"	3'-6"	4'-6"	3'-3"
14	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							
18	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							

Lap Splices - Deformed Bars in Tension (Cont'd)

Class B

Center to Center Spacing < 6" or Clear Cover < 3"								
ℓ_{sp} = 1.3 * Development Length ℓ_d								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-5"	1'-4"	1'-5"	1'-4"	1'-5"	1'-4"	1'-5"	1'-4"
4	1'-10"	1'-4"	1'-10"	1'-4"	1'-10"	1'-4"	1'-10"	1'-4"
5	2'-4"	1'-8"	2'-4"	1'-8"	2'-4"	1'-8"	2'-4"	1'-8"
6	2'-11"	2'-1"	2'-9"	2'-0"	2'-9"	2'-0"	2'-9"	2'-0"
7	4'-0"	2'-10"	3'-5"	2'-6"	3'-3"	2'-4"	3'-3"	2'-4"
8	5'-3"	3'-9"	4'-6"	3'-3"	4'-1"	2'-11"	3'-8"	2'-8"
9	6'-7"	4'-9"	5'-9"	4'-1"	5'-1"	3'-8"	4'-8"	3'-4"
10	8-5"	6'-0"	7'-3"	5'-2"	6'-6"	4'-8"	5'-11"	4'-3"
11	10'-3"	7'-4"	8'-11"	6'-5"	8'-0"	5'-8"	7'-3"	5'-3"
14	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							
18	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							

Class B

Center to Center Spacing ≥ 6" & Clear Cover ≥ 3"								
ℓ_{sp} = 1.3 * Development Length ℓ_d								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-4"	1'-4"	1'-4"	1'-4"	1'-4"	1'-4"	1'-4"	1'-4"
4	1'-6"	1'-4"	1'-6"	1'-4"	1'-6"	1'-4"	1'-6"	1'-4"
5	1'-10"	1'-4"	1'-10"	1'-4"	1'-10"	1'-4"	1'-10"	1'-4"
6	2'-4"	1'-8"	2'-3"	1'-7"	2'-3"	1'-7"	2'-3"	1'-7"
7	3'-2"	2'-4"	2'-9"	2'-0"	2'-7"	1'-10"	2'-7"	1'-10"
8	4'-2"	3'-0"	3'-8"	2'-7"	3'-3"	2'-4"	3'-0"	2'-2"
9	5'-4"	3'-10"	4'-7"	3'-3"	4'-1"	2'-11"	3'-9"	2'-8"
10	6'-9"	4'-10"	5'-10"	4'-2"	5'-2"	3'-9"	4'-9"	3'-5"
11	8'-3"	5'-11"	7'-2"	5'-1"	6'-5"	4'-7"	5'-10"	4'-2"
14	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							
18	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							

Lap Splices - Deformed Bars in Tension (Cont'd)

Class C

Center to Center Spacing < 6" or Clear Cover < 3"								
ℓ_{sp} = 1.7 * Development Length ℓ_d								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-10"	1'-9"	1'-10"	1'-9"	1'-10"	1'-9"	1'-10"	1'-9"
4	2'-5"	1'-9"	2'-5"	1'-9"	2'-5"	1'-9"	2'-5"	1'-9"
5	3'-0"	2'-2"	3'-0"	2'-2"	3'-0"	2'-2"	3'-0"	2'-2"
6	3'-10"	2'-9"	3'-7"	2'-7"	3'-7"	2'-7"	3'-7"	2'-7"
7	5'-2"	3'-9"	4'-6"	3'-3"	4'-2"	3'-0"	4'-2"	3'-0"
8	6'-10"	4'-11"	5'-11"	4'-3"	5'-4"	3'-10"	4'-10"	3'-6"
9	8'-8"	6'-2"	7'-6"	5'-4"	6'-8"	4'-9"	6'-1"	4'-5"
10	10'-11"	7'-10"	9'-6"	6'-9"	8'-6"	6'-1"	7'-9"	5'-7"
11	13'-5"	9'-7"	11'-8"	8'-4"	10'-5"	7'-5"	9'-6"	6'-10"
14	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							
18	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							

Class C

Center to Center Spacing ≥ 6" and Clear Cover ≥ 3"								
ℓ_{sp} = 1.7 * Development Length ℓ_d								
Concrete	f_c' = 3.0 ksi		f_c' = 4.0 ksi		f_c' = 5.0 ksi		f_c' = 6.0 ksi	
Bar Size	Top Bars	Others	Top Bars	Others	Top Bars	Others	Top Bars	Others
3	1'-9"	1'-9"	1'-9"	1'-9"	1'-9"	1'-9"	1'-9"	1'-9"
4	1'-11"	1'-9"	1'-11"	1'-9"	1'-11"	1'-9"	1'-11"	1'-9"
5	2'-5"	1'-9"	2'-5"	1'-9"	2'-5"	1'-9"	2'-5"	1'-9"
6	3'-1"	2'-2"	2'-11"	2'-1"	2'-11"	2'-1"	2'-11"	2'-1"
7	4'-2"	3'-0"	3'-7"	2'-7"	3'-4"	2'-5"	3'-4"	2'-5"
8	5'-6"	3'-11"	4'-9"	3'-5"	4'-3"	3'-0"	3'-11"	2'-9"
9	6'-11"	4'-11"	6'-0"	4'-3"	5'-4"	3'-10"	4'-11"	3'-6"
10	8-9"	6'-3"	7'-7"	5'-5"	6'-10"	4'-10"	6'-2"	4'-5"
11	10'-9"	7'-8"	9'-4"	6'-8"	8'-4"	6'-0"	7'-7"	5'-5"
14	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							
18	Lap splice shall not be allowed per AASHTO LRFD 5.11.5.2.1							

Lap Splices of Bars in Compression

Splice Lengths of Bars in Compression AASHTO 5.11.5.5						
Reinforcement f_y = 60 ksi						
Concrete		**f_c' ≥ 3.0 ksi**			**f_c' < 3.0 ksi**	
	ℓ_{cb}	**with Tie**	**With Spirals**	**Other cases**	**ℓ_{cb}**	
		λ=0.83	**λ=0.75**	**λ=1.0**		**λ=1.0**
Bar Size	**$0.5*f_y*d_b$**	**$\ell_c = \lambda*\ell_{cb}$**	**$\ell_c = \lambda*\ell_{cb}$**	**$\ell_c = \lambda*\ell_{cb}$**	**$0.5*1.33*fy*d_b$**	**$\ell_c = \lambda*\ell_{cb}$**
	in	**in**	**in**	**in**	**in**	**in**
3	11.3	1’-0”	1’-0”	1’-0”	15	1’-3”
4	15	1’-1”	1’-0”	1’-3”	20	1’-8”
5	18.8	1’-4”	1’-3”	1’-7”	24.9	2’-1’
6	22.5	1’-7”	1’-5"	1’-11”	29.9	2’-6’
7	26.3	1’-10”	1’-8”	2’-3”	34.9	2’-11”
8	30	2’-1”	1’-11”	2’-6”	39.9	3’-4”
9	33.8	2’-5”	2’-2”	2’-10”	45	3’-9”
10	38.1	2’-8”	2’-5”	3’-3”	50.7	4’-3”
11	42.3	3’-0”	2’-8”	3’-7”	56.3	4’-9”
14	50.8	3’-7”	3’-3”	4’-3”	67.5	5’-8”
18	67.7	4’-9”	4’-3”	5’-8”	90	7’-6”

Notes:

1. Values of ℓ_{cb} and ℓ_c in the table are for reinforcement, yield strength f_y = 60 ksi only. For reinforcement f_y < 60 ksi, the values of ℓ_c or ℓ_{cb} may be multiplied by fy / 60 ksi. If f_y > 60 ksi, use AASHTO Eq (5.11.5.5.1-2) to compute ℓ_c and ℓ_{cb} instead of the values in the table.

2. The length of lap ℓ_c shall not be less than 12”.

3. Ties along the splice should have an effective area not less than 0.15 percent of the product of the thickness of the compression component times the tie spacing.

4. Where bars of different size lap spliced on compression, the splice length shall not be less than the development length of the larger bar or the splice length of the smaller bar. Bar size 14 and 18 may be lapped to 11 or smaller bars.

Modification Factors to Basic Development Lengths

Deformed Straight Bars in Tension:

Development length ℓ_d shall be the product of the basic development length, ℓ_{db} in the table and the modification factor or factors (λ). For the cases not included in the chapter, see AASHTO LRFD 5.11.2.1.2 and 5.11.2.1.3 for bars in tension.

Modification Factors (λ) for Straight Bars in Tension

	Modification Factor (λ)
Modification factors (λ) which increase development length ℓ_d:	
Top horizontal bars with more than 12" of fresh concrete below the bars	1.4
Lightweight aggregate concrete where f_{ct} (ksi) is specified	$0.22*(f_c')^{\wedge 0.5} / f_{ct} \geq 1.0$
All-lightweight concrete where f_{ct} is not specified	1.3
Sand-lightweight concrete where f_{ct} is not specified	1.2
Modification factors (λ) which decrease development length ℓ_d:	
Bars spaced laterally not less than 6" center to center and 3" clear cover measured in direction of the spacing	0.8
Bars enclosed within a spiral not less than 0.25" diameter and not more than 4" pitch	0.75
Anchorage or development for the full yield strength of reinforcement is not required, or where reinforcement provided is in excess of that required by analysis	$A_{s\text{-required}} / A_{s\text{-provided}}$

Modification Factors to Basic Development Lengths (cont'd)

Deformed Straight Bars in Compression:

The basic development length, ℓ_{db} for bars in compression may be multiplied by the following applicable modification factors. For the cases not included in the chapter, see AASHTO LRFD 5.11.2.2.

Modification Factors (λ) for Straight Bars in Compression

	Modification Factor (λ)
Bars enclosed within a spiral not less than 0.25" diameter and not more than 4" pitch	0.75
Lightweight aggregate concrete	1.3
Anchorage or development for the full yield strength of reinforcement is not required, or where reinforcement provided is in excess of that required by analysis	$A_{s\text{-required}} / A_{s\text{-provided}}$

Standard Hooks in Tension:

The development length, ℓ_{dh}, in inch for standard hooked deformed bars in tension shall be the product of the basic development length ℓ_{hb} and the applicable modification factor(s) below, and the development length shall not less than 8* bar diameters and 6". For the cases not included here, see AASHTO LRFD 5.11.2.4.

Modification Factors (λ) Standard Hooks in Tension

	Modification Factor (λ)
Hook bars with yield strength f_y > 60 ksi	f_y / 60.0
Side cover for No. 11 bar and smaller, normal to plane of hook, is not less than 2.5" and 90° hook, cover on bar extension beyond hook not less than 2.0"	0.7
Hooks for No. 11 bar or smaller enclosed vertically of horizontally within ties or stirrup ties which are spaced along the full development length ℓ_{dh} not greater than 3*diameter of the hooked bar	0.8
Lightweight aggregate concrete	1.3
Anchorage or development for the full yield strength of reinforcement is not required, or where reinforcement provided is in excess of that required by analysis	$A_{s\text{-required}} / A_{s\text{-provided}}$

Welded Wire, Shear Reinforcement and Mechanical Devices

For deformed / welded wire fabric, shear reinforcement and mechanical anchorage devices, and any other situations not covered in the chapter, see the current AASHTO LRFD specifications.

Marking System for Reinforcement in Bridges

Reinforcing bars must have identification on engineering drawing to avoid confusion and to facilitate proper placement of bars in various parts of the structure.

The Structure and Bridge Division has adopted a standardized marking system. This system makes it convenient for the fabricator to fabricate, bundle, tag, and deliver the reinforcing bars, as well as provides the convenience of bar sizes provided on all detailed drawings.

All reinforcing bars are to be designated by a six-character mark which will be used on the engineering drawings and reinforcing steel schedules. The marking system will consist of a group of letters and numbers.

The first character consists of a letter to indicate the major part of the structure in which the bar is located. The type of structure element is usually indicated by the following letters.

A - Abutments
P - Piers
S - Superstructure Slab
R - Railing, Parapet
M - Median
E - End (usually used for slab end bars on skewed slabs)
B - Concrete Beam

The second character consists of a letter to indicate the type of reinforcing bar or its more precise location within the major structural element. The bars are usually indicated by the following letters:

F - Footings
S - Stirrups, Seats, Slab
V - Vertical
P - Pads
H - Horizontal
W - Wingwall, Sidewalk
L - Longitudinal
B - Bent, Backwall, Spiral, Slab, Terminal Wall
N - Nose
T - Temperature, Terminal Wall, Tie, Transverse
C - Caps, Slab (straight)
P - Diaphragm
D - Diaphragm
K - “K” Parapet

Third and fourth characters consist of two numbers to designate the bar size, such as:

04 - #4 bar
06 - #6 bar
11 - #11 bar

The fifth and sixth characters consist of two numbers to designate the order in the same group of bars, such as:

01 - first bar in the lettered series
02 - second bar in the lettered series
03 - third bar in the lettered series

Examples: #8 Bar in pier footing: PF0801
#4 Bar in pier footing: PF0402
#5 Bar in pier footing: PF0503

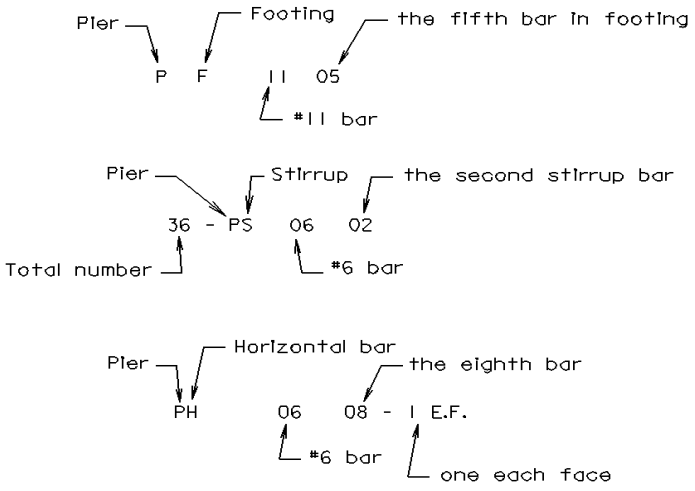
Marking System for Reinforcement in Bridge (Cont'd)

Additional marks also can be used to clarify the drawing but will not be used with the reinforcing schedules. Examples are:

N.F.	- Near Face
F.F.	- Far Face
E.F.	- Each Face
1 E.F.	- One Each Face
Bottom	
Top	

A number followed by a dash before the mark can be used to indicate the number of bars in the same place when only one bar is visible on the drawing.

Several sample designations are explained below:



THE FOLLOWING NOTES SHALL BE PLACED ON THE REINFORCING STEEL SCHEDULE(S):

NOTES: Dimensions in the bending diagram are out-to-out of bars.

If fabrication of deck slab bars is not possible for the length detailed and multiple bars are required, bars shall have the least number of Class B splices possible. Splices shall be located approximately at points of contraflexure, and splices in alternate bars shall be located in different bays.

Full length straight bars (top and bottom) may be substituted for truss bars (SB Series) in the deck superstructure at no extra cost to the Department.

These notes are automatically placed on the Reinforcing Steel Sheets when the VDOT MDL program is run and a plot request is made.