SUPERELEVATION TRANSITIONS

202-4

REFERENCE SECTION
202.4.5 & 202.4.8

Maximum Relative Gradient for Profiles Between the Edge of Traveled Way and the Centerline or Reference Line (Axis of Rotation)		
Design Speed (mph)	Maximum Relative Gradient (Percent) "△"	Equivalent Maximum Relative Slope "G"
20	0.74	135:1
25	0.70	143:1
30	0.66	152:1
35	0.62	161:1
40	0.58	172:1
45	0.54	185:1
50	0.50	200:1
55	0.47	213:1
60	0.45	222:1
65	0.43	233:1
70	0.40	250:1
75	0.38	263:1

Adjustment Factors, b_w		
Number of Lanes, Rotated n_1	Divided * Roadways b_w	Undivided Roadways b_w
1	1.00	1.00
1.5	1.00	0.83
2	1.00	0.75
2.5	1.00	0.70
3	1.00	0.67
3.5	1.00	0.64

* Interstates, Freeways, Expressways and Ramps

In Figures 202-7, 202-8 and 202-10, the table values for the Minimum Length of Superelevation Runoff, L_r, were determined by the following equation:

$$L_r = \frac{(w \times n_1)\, e_d}{\triangle} (b_w) \times 100 \qquad \text{or} \qquad L_r = (w \times n_1)(e_d)(G)(b_w)$$

The equation can also be used to determine L_r, when more than one lane is rotated about the centerline or the edge or if the lane width is other than 12 feet for Figures 202-7 and 202-8 or 16 feet for Figure 202-10.

Once L_r has been determined, the Minimumum Length of Tangent Runout, L_t,should be determined by the following equation:

$$L_t = (e_{NC} \div e_d)\, L_r$$

The equation for L_t can be used by Figures 202-7, 202-8, 202-9 and 202-10.

Where:

L_r = minimum length of superelevation runoff, ft
L_t = minimum length of tangent runout, ft
$\triangle$ = maximum relative gradient, percent
n_1 = number of lanes rotated
w = width of one traffic lane, ft (typically 12 ft)
e_d = design superelevation rate
e_{NC} = normal cross slope rate, (0.016)
G = equivalent maximum relative slope, (the reciprocal of $\triangle$)
b_w = adjustment factor for number of lanes rotated

SUPERELEVATION AND RUNOFF LENGTHS FOR HORIZONTAL CURVES ON RURAL HIGHWAYS - Based on Max. S.E. of 0.08 ft/ft -

202-7

REFERENCE SECTION 202.4.1, 202.4.3,

Ex. eMAX @ Exit = 0.028 --> 33mph

Ex. eMAX @ Entrance = 0.036 --> 39mph
Ex. Design eMAX = 0.04 --> 41mph

Dc	RADIUS	DESIGN SPEED 25		30		35		40		45		50		55		60	
		e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r
0°15′	22918	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
0°30′	11459	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
0°45′	7639	NC	--	NC	--	NC	--	NC	--	NC	--	.016	39	.019	49	.022	59
1°00′	5730	NC	--	NC	--	NC	--	NC	--	.017	38	.021	51	.025	64	.029	78
1°30′	3820	NC	--	NC	--	.017	33	.021	44	.025	56	.030	72	.035	90	.041	110
2°00′	2865	NC	--	.017	32	.022	43	.027	56	.032	72	.038	92	.045	116	.051	136
2°30′	2292	NC	--	.021	39	.026	51	.033	69	.039	87	.046	111	.053	136	.061	163
3°00′	1910	.018	31	.024	44	.031	60	.038	79	.045	100	.053	128	.060	154	.068	182
3°30′	1637	.021	37	.028	52	.035	68	.043	89	.050	111	.058	140	.066	169	.074	198
4°00′	1432	.024	42	.031	57	.039	76	.047	98	.055	123	.063	152	.071	182	.078	208
4°30′	1273	.026	45	.034	63	.042	82	.051	106	.059	131	.068	164	.075	192	.080	214
5°00′	1146	.029	50	.037	68	.046	89	.055	114	.063	140	.071	171	.078	200		
5°30′	1042	.031	54	.040	73	.049	95	.058	120	.066	147	.074	178	.080	205		
6°00′	955	.033	57	.042	77	.051	99	.061	126	.070	156	.077	185				
6°30′	881	.035	61	.045	83	.054	105	.063	131	.072	160	.079	190				
7°00′	819	.037	64	.047	86	.056	109	.066	137	.074	165	.080	192				
7°30′	764	.039	67	.049	90	.058	113	.068	141	.076	169	.080	192				
8°00′	716	.041	71	.051	94	.060	116	.070	145	.078	174						
8°30′	674	.042	73	.052	95	.062	120	.072	149	.079	176						
9°00′	637	.044	76	.054	99	.064	124	.074	153	.080	178						
9°30′	603	.046	79	.055	101	.066	128	.075	155	.080	178						
10°00′	573	.047	81	.057	104	.067	130	.077	159								
10°30′	546	.048	83	.058	106	.069	134	.078	161								
11°00′	521	.049	85	.059	108	.070	136	.079	164								
11°30′	498	.050	86	.061	112	.071	138	.079	164								
12°00′	477	.051	88	.062	114	.073	142	.080	166								
12°30′	458	.052	90	.063	115	.074	143	.080	166								
13°00′	441	.053	91	.064	117	.075	145										
13°30′	424	.054	93	.066	121	.076	147										
14°00′	409	.055	95	.067	123	.077	149										
14°30′	395	.056	97	.068	125	.077	149										
15°00′	382	.057	98	.069	126	.078	151										
16°30′	347	.059	102	.071	130	.079	153										
18°00′	318	.062	107	.074	135	.080	155										
20°00′	286	.064	110	.076	139												
22°00′	260	.067	115	.078	143												
23°00′	249	.068	117	.079	145												
25°00′	229	.071	122	.080	146												
26°30′	216	.072	124	.080	146												
28°00′	205	.074	127														
31°00′	185	.076	131														
34°00′	169	.078	134														
36°00′	159	.079	136														
38°00′	151	.079	136														
40°00′	143	.080	138														
42°00′	136	.080	138														

△=4°46′30″
▲=0°32′

△=5°58′05″
▲=0°38′

△=7°33′30″
▲=0°45′

△=9°45′40″
▲=0°55′

△=12°54′15″
▲= 1°08′

△=18°14′50″
▲= 1°26′

△=26°46′25″
▲= 1°53′

△=42°45′30″
▲= 2°35′

NC = Normal Crown

△ = Max. Dc for the Design Speed
▲ = Max. Dc Without Superelevation

Dc	RADIUS	DESIGN SPEED 65		70		75	
		e_d	L_r	e_d	L_r	e_d	L_r
0°15′	22918	NC	--	NC	--	NC	--
0°30′	11459	.017	48	.019	57	.021	67
0°45′	7639	.025	70	.028	84	.031	98
1°00′	5730	.032	90	.036	108	.040	127
1°15′	4584	.039	110	.044	132	.049	155
1°30′	3820	.046	129	.051	153	.058	184
1°45′	3274	.052	146	.058	174	.066	209
2°00′	2865	.058	163	.065	195	.073	231
2°15′	2546	.063	177	.071	213	.078	247
2°30′	2292	.068	191	.075	225	.080	253
2°45′	2083	.072	202	.078	234		
3°00′	1910	.075	210	.080	240		
3°15′	1763	.078	219				
3°30′	1637	.079	221				
3°45′	1528	.080	224				

△=2°35′35″
▲=0°23′

△=3°09′55″
▲=0°25′

△=3°52′15″
▲=0°28′

Ex. Design eMAX (I-80) = 0.04 --> 65mph

e_d= Design Superelevation Rate
L_r= Min. Runoff Length, 2-Lane Highway Rotated About the Centerline, Lane Width of 12 feet

JULY 2024

MAXIMUM CHANGE IN VERTICAL ALIGNMENT WITHOUT VERTICAL CURVE

203-2

REFERENCE SECTION
203.3.2

DESIGN SPEED (mph)	MAX. GRADE CHANGE △
25	1.85%
30	1.30%
35	0.95%
40	0.75%
45	0.55%
50	0.45%
55	0.40%
60	0.30%
65	0.30%
70	0.25%
75	0.20%

10 11.65%
15 5.15%
20 2.9%

Based on the AASHTO comfort formula for sag vertical curves:

$$A = 46.5\ L / V^2 = 1162.5 / V^2$$

Where:

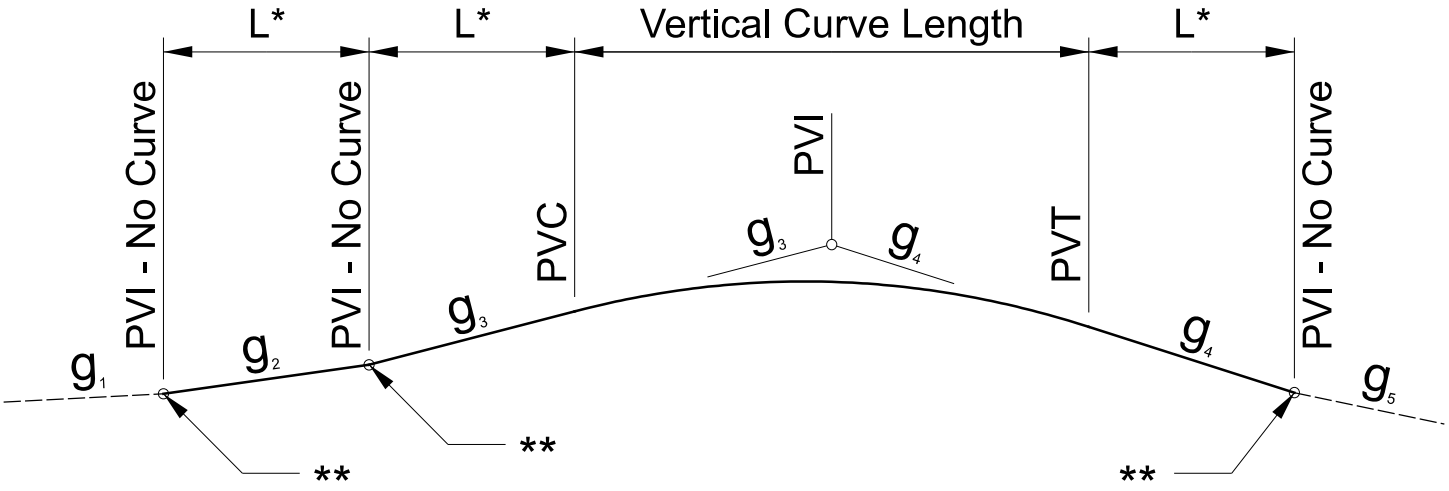
A = Maximum Grade Change (%)

L = Length of Vertical Curve (assume 25')

V = Design Speed (mph)

△ ROUNDED TO NEAREST 0.05%

RELATIONSHIP BETWEEN VERTICAL CURVES AND GRADE BREAKS



* The minimum distance between consecutive deflections is:
100' where design speed is 50 mph or greater
50' where design speed is less than 50 mph

** Allowable grade break location.

INTERCHANGE ELEMENTS - TRAVELED WAY, SHOULDERS AND MEDIANS

303-1

REFERENCE SECTIONS
303.1

INTERCHANGE ELEMENTS	TOTAL TRAVELED WAY WIDTH	Graded Shoulder Width				Paved Shoulder Width		Normal Rounding (E)	Guardrail Offset (From Traveled Way) (G)	
		Left		Right						
		With Barrier or Foreslope steeper than 6:1	w/o Barrier slopes 6:1 or flatter	With Barrier or Foreslope steeper than 6:1	w/o Barrier slopes 6:1 or flatter	LT	RT		LT	RT
Ramp	16' (A)	9' (C) 8'?	6' 5'?	11' (C)	8'	3'	6'	10' 5'?	6'	8'
1-Lane Directional Roadway	16' (A)	9' (C)	6'	11' (C)	8'	4'	6'	10'	6'	8'
2-Lane Directional Roadway or Multilane Ramps	Var. (B)	9' (C)(H)	6' (H)	15' (D)	10' (D)	4' (H)	10'	10'	6' (H)	12' (D)
Accel/Decel Lane or Combined	Var.	NA	NA	13' (D)(F)	8' (D)(F)	NA	8' (F)	10'	NA	10' (D)(F)

NOTES:

(A) Use 18 ft. when inside traveled way edge radius is less than 200 ft.

(B) For 2-lane directional roadways and 2-lane multilane ramps, the traveled way width shall be 24 ft.

(C) May be reduced 1 ft. if the face of the mainline barrier is 2 ft. from the outside edge of the treated shoulder.

(D) Or match mainline dimension if lesser.

(E) Rounding is 4 ft. when barrier is used. No rounding is required when foreslope is 6:1 or flatter.

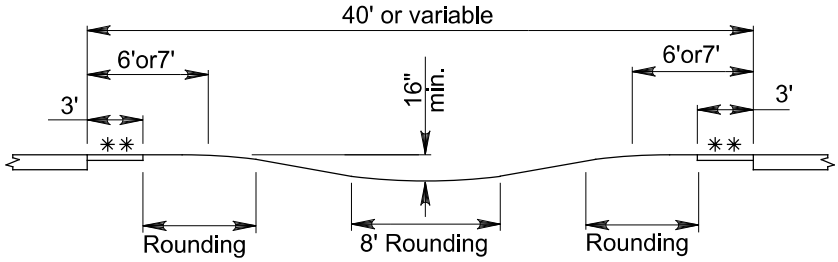
(F) Match Multilane Ramp dimensions when used with Multilane Ramps.

(G) Concrete barrier may be placed at the edge of the paved shoulder when used in lieu of guardrail, but no closer than 4'.

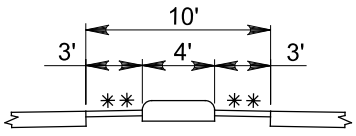
(H) For 3 or more lanes, use right side widths or dimensions.

Should this be modified to match note (P) from 301-3? Total Graded Width may be reduced as much as 3-ft. where MGS guardrail with the longer posts is used. See Section 603.1.2 and SCD MGS-1.1 for post length and position details.

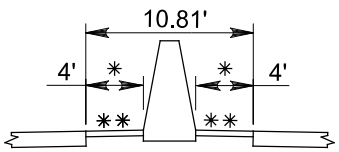
TWO-WAY RAMP MEDIAN



MINIMUM TWO-WAY RAMP - CONCRETE MEDIAN



MINIMUM TWO-WAY RAMP - CONCRETE BARRIER MEDIAN



* Check horizontal stopping sight distance

** See Figure 301-8 for shoulder cross slope

RAMP DESIGN SPEED GUIDE

503-1

REFERENCE SECTIONS
503.2

RAMP DESIGN SPEED (mph)	MAINLINE DESIGN SPEED (mph)									
	30	35	40	45	50	55	60	65	70	75
UPPER RANGE	25	30	35	40	45	48	50	55	60	65
MIDDLE RANGE	20	25	30	33	35	40	45	45	50	55
LOWER RANGE	15	18	20	23	25	28	30	30	35	40

Note: Ramp design speeds do not pertain to the ramp terminals.

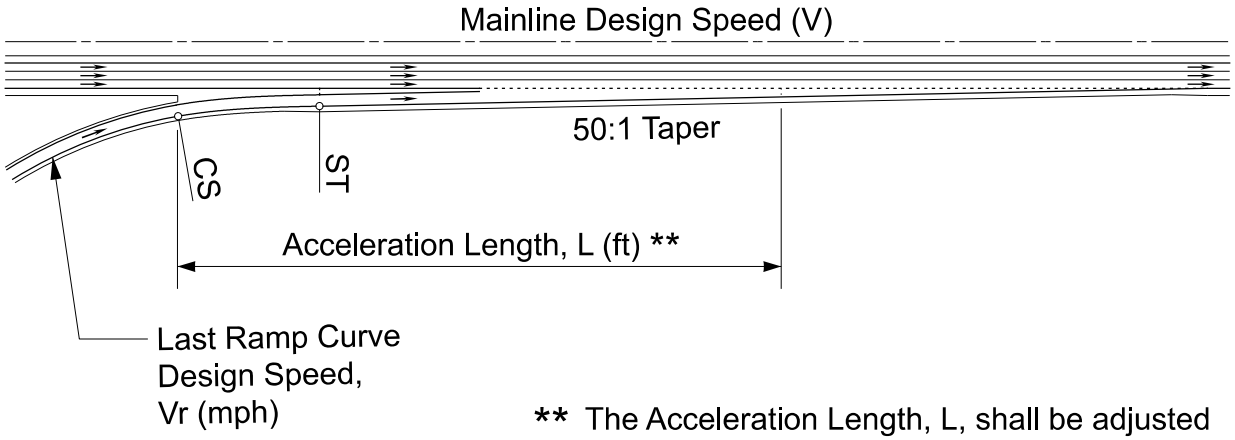
MINIMUM ACCELERATION LENGTHS FOR HIGH-SPEED ENTRANCE TERMINALS WITH FLAT GRADES OF 2% OR LESS

503-2a

REFERENCE SECTION
503.6.2

Mainline Design Speed, V (mph)	Acceleration Length, L (ft) for design Speed of Last Ramp Curve, Vr (mph)								
	Stop	15	20	25	30	35	40	45	50
50	720	660	610	550	450	350	130	-	-
55	960	900	810	780	670	550	320	150	-
60	1200	1140	1100	1020	910	800	550	420	180
65	1410	1350	1310	1220	1120	1000	770	600	370
70	1620	1560	1520	1420	1350	1230	1000	820	580
75	1790	1730	1630	1580	1510	1420	1160	1040	780

Ex. eMAX = 0.035 --> 38mph --> 862' --> 518' adjusted for grade



** The Acceleration Length, L, shall be adjusted for Grade with Figure 503-2b.

HIGH-SPEED ENTRANCE TERMINAL ADJUSTMENT FACTORS AS A FUNCTION OF GRADE

503-2b

REFERENCE SECTION
503.6.2

Mainline Design Speed, V (mph)	Ratio of Length On Grade to Length On Level for Design Speed of Last Ramp Curve, Vr (mph) *							
	20	25	30	35	40	45	50	All Speeds
	3 to 4% upgrade							3 to 4% downgrade
50	1.30	1.35	1.40	1.40	1.40	-	-	0.650
55	1.35	1.40	1.45	1.45	1.45	-	-	0.625
60	1.40	1.45	1.50	1.50	1.50	1.55	1.60	0.600
65	1.45	1.50	1.55	1.55	1.60	1.65	1.70	0.600
70	1.50	1.55	1.60	1.65	1.70	1.75	1.80	0.600
	5 to 6% upgrade							5 to 6% downgrade
50	1.50	1.60	1.70	1.80	1.90	-	-	0.550
55	1.60	1.70	1.80	1.90	2.05	-	-	0.525
60	1.70	1.80	1.90	2.05	2.20	2.35	2.50	0.500
65	1.85	1.95	2.05	2.20	2.40	2.60	2.75	0.500
70	2.00	2.10	2.20	2.40	2.60	2.80	3.00	0.500

No adjustment required for Grades less than 3%. Existing I-80 WB grade = 3.0% downgrade

* Ratio from this table multiplied by acceleration length in Figure 503-2a gives acceleration length on grade.

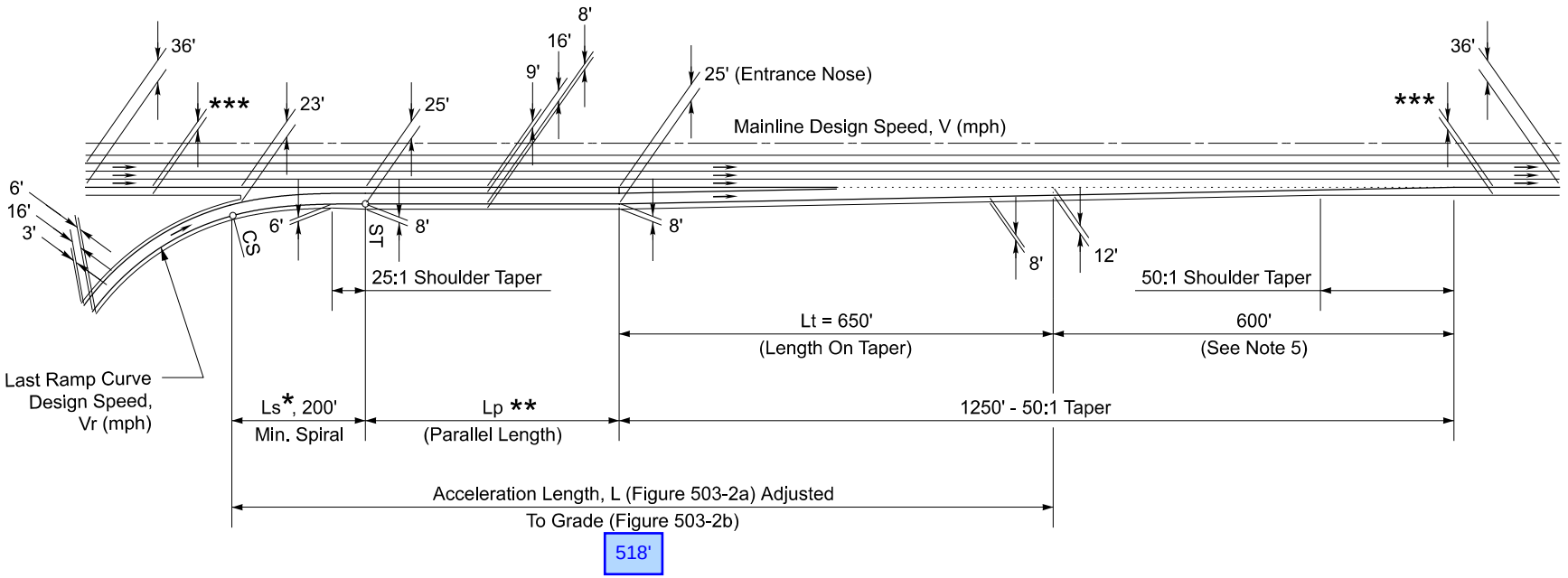
The "grade" in the table is the Average Grade measured over the distance for which the Acceleration Length applies.

For Mainline Design Speeds greater than 70 mph, use 70 mph design speed Adjustment Factors.

HIGH-SPEED SINGLE-LANE ENTRANCE TERMINAL

503-2c

REFERENCE SECTIONS 503.6.2



* Length may be increased for Superelevation Transition

** To determine Lp, subtract Ls and Lt from L.

*** Mainline Paved Shoulder Width as required by Figure 301-3 or 301-4.

Notes For Single Lane Entrance Terminals

1. The minimum Acceleration Length, L, shall be Ls + Lt.
2. The 9' to 23' variable width of Treated Shoulder of the Entrance Terminal shall be sloped for 12' as required for mainline design (usually ½in./ft.), except for the last 100' to 200' at the 9' end, which is to be sloped as required for proper terminal grading.
3. Normally Single Lane Ramps will have a Width of 16'. The Width shall be increased to 18' when the Ramp Radius is less than 200'. When an 18' wide ramp is used, the 25' Entrance Terminal Width shall be retained and the 9' width reduced by 2'.
4. If Lp (Parallel Length) is not required (L <= 850'), then the 200' minimum Spiral should be tangent to the 50:1 Taper.
5. If the Entrance Terminal results in an add-lane (no merge), delete the last 600' of the 50:1 Taper.

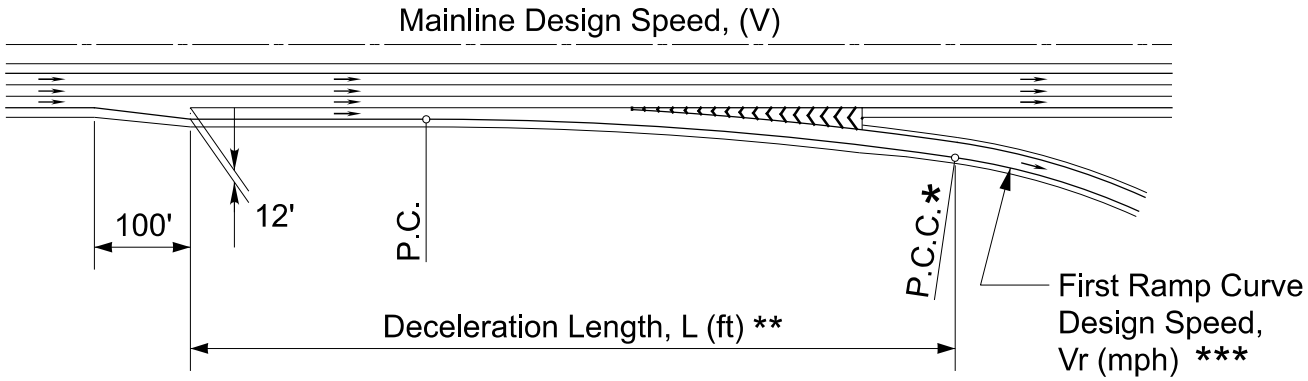
MINIMUM DECELERATION LENGTHS FOR HIGH-SPEED EXIT TERMINALS WITH FLAT GRADES OF 2% OR LESS

503-3a

REFERENCE SECTION
503.6.3

Mainline Design Speed, V (mph)	Deceleration Length, L (ft) for Design Speed of First Ramp Curve, Vr (mph) ***								
	Stop	15	20	25	30	35	40	45	50
50	435	405	385	355	315	285	225	175	-
55	480	455	440	410	380	350	285	235	-
60	530	500	480	460	430	405	350	300	240
65	570	540	520	500	470	440	390	340	280
70	615	590	570	550	520	490	440	390	340
75	660	635	620	600	575	535	490	440	390

Ex. eMAX = 0.028 --> 33mph --> 452' adjusted for grade



* P.C.C. Or Mid-Point of 200' Spiral

** The minimum Deceleration Length, L, after Adjustment For Grade (Figure 503-3b), shall be 800'

*** Or other Design Speed limiting Geometric Control such as the Stopping Sight Distance for a Vertical Curve or the back of a Traffic Queue.

HIGH-SPEED EXIT TERMINAL ADJUSTMENT FACTORS AS A FUNCTION OF GRADE

503-3b

REFERENCE SECTION
503.6.3

Mainline Design Speed, V (mph)	Ratio of Length On Grade to Length On Level for Design Speed of First Ramp Curve, Vr (mph) *	
	All Speeds	All Speeds
	3 to 4% upgrade	3 to 4% downgrade
All Speeds	0.90	1.20
	5 to 6% upgrade	5 to 6% downgrade
All Speeds	0.80	1.35

No adjustment required for Grades less than 3%. Existing I-80 WB grade = 1.1% upgrade

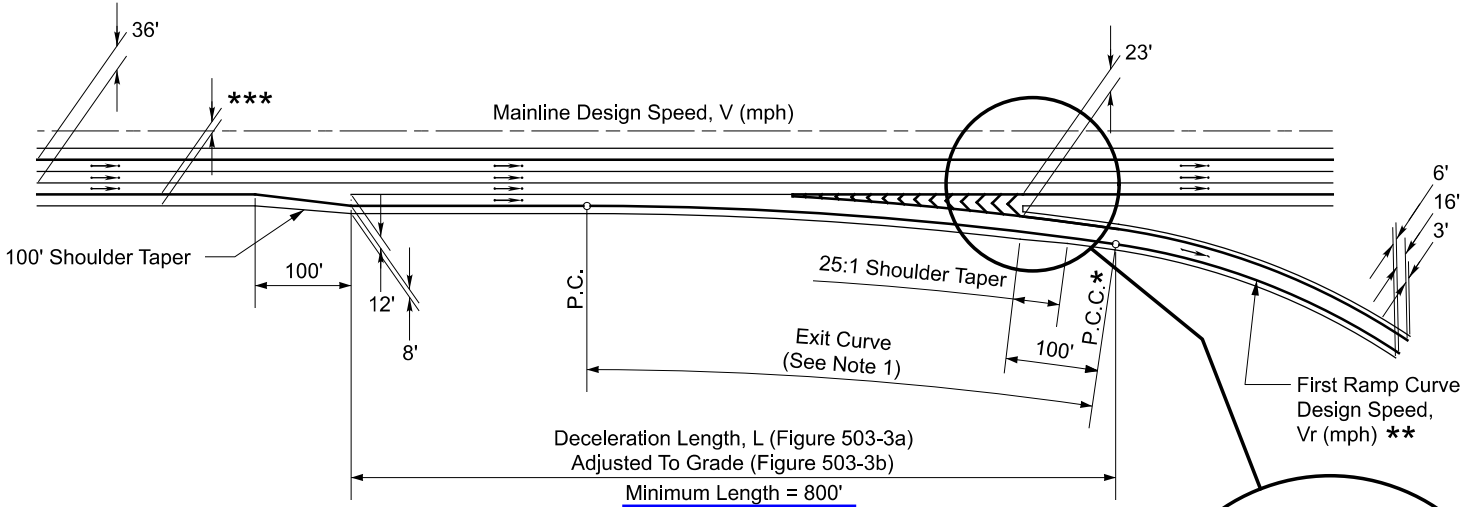
* Ratio from this table multiplied by Deceleration Length in Figure 503-3a gives Deceleration Length On Grade.

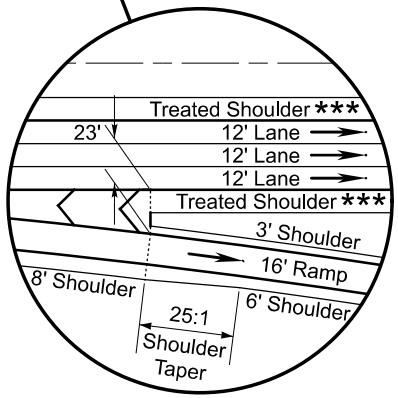
The "grade" in the table is the Average Grade measured over the distance for which the Deceleration Length applies.

HIGH-SPEED SINGLE-LANE EXIT TERMINAL

503-3c

REFERENCE SECTIONS 503.6.3





GORE DETAIL

EXIT CURVE TABLE		
Mainline Design Speed, V (mph)	Maximum Exit Curvature, Dc	
	Rural	Urban
75	1°- 13'	1°- 22'
70	1°- 24'	1°- 35'
65	1°- 35'	1°- 55'
60	1°- 50'	2°- 15'
55	2°- 10'	2°- 45'
50	2°- 40'	3°- 30'

Ex. Dc = 2d5'

* P.C.C. Or Mid-Point of 200' Spiral

** Or other Design Speed limiting Geometric Control such as the Stopping Sight Distance for a Vertical Curve or the back of a Traffic Queue.

*** Mainline Paved Shoulder Width as required by Figure 301-3 or 301-4.

Notes For High-Speed Single-Lane Exit Terminals

1. The Exit Curve should normally be according to the Exit Curve Table where the mainline is on tangent. Where the mainline is on curving alignment, the maximum differential between the Exit Curve and the mainline curve should normally be the Exit Curve Table value. This differential, however, may vary by as much as one degree in order to avoid a tangent exit alignment. (See Section 503.6.4 for the allowable Transverse Breaks in Superelevation Cross-Sope.)

2. When the First Ramp Curve does not exceed 8°, the Exit Curve may be compounded directly with the First Ramp Curve at a PCC 100' beyond the nose. When the First Ramp Curve does exceed 8°, a spiral should be placed between the Exit Curve and the First Ramp Curve and the beginning of the spiral (CS) should be at the nose.

3. Normally Single Lane Ramps will have a Width of 16'. The Width shall be increased to 18' when the Ramp Radius is less than 200'. When an 18' wide ramp is used, the 39' Exit Terminal Width shall be retained and the 23' width reduced by 2'.