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MINNESOTA DEPARTMENT OF TRANSPORTATION	**TRANSMITTAL LETTER NO. (19-01)**
DEVELOPED BY: Design Standards Unit	**MANUAL:** Road Design Manual
ISSUED BY: Office of Project Management and Technical Support	**DATED:** May 7, 2019
SUBJECT: Minor Corrections Chapters 3 & 6	

A list of changes is attached to this update.

INSTRUCTIONS:

1. Record this transmittal letter number, date and subject on the transmittal record sheet located in the front of the manual. The last Transmittal Letter was 18-01, dated November 28, 2018.

2. Remove from the manual: Section 3-2(3-6)
   Section 3-3(1-20)
   Section 6-3(3-6)

3. Insert into the manual: Section 3-2(3-6)
   Section 3-3(1-23)
   Section 6-3(3-6)

   All updated sheets are dated May, 2019.

4. The Road Design Manual and associated Transmittal Letters are available online in PDF format at. http://roaddesign.dot.state.mn.us/roaddesign.aspx

5. Any technical questions regarding this transmittal should be directed to Mike Elle, Design Standards Engineer, at (651) 366-4622, or by email to DesignStandards.DOT@state.mn.us

Michael Elle

Michael Elle, P.E.
Design Standards Engineer

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Summary of Changes
MnDOT Road Design Manual
19-01

Throughout

- "Flipping" of units of measure, where needed, to put U.S. Customary first in order

Section 3-2 HORIZONTAL ALIGNMENT

- 3-2.03 Superelevation and Side Friction
  - Relocate the 3rd paragraph text to lead off first paragraph for more logical flow
    - Delete the first sentence, as it better pertains to Section 3-3
  - 4th Paragraph:
    - Relocate the first half to the second paragraph and enhance with safety discussion (margin against skidding)
    - Delete the second half, as it pertains to superelevation distributions in Section 3-3 and only confuses matters here
- 3-2.04 Maximum Degree (Minimum Radius) of Horizontal Curve
  - Update the maximum superelevation rate to 8%
  - Various editorial wordsmithing
  - Restate guidance on use of maximum curvature in light of known performance effects
  - Make horizontal sight distance consideration parenthetical and provide reference
  - Add exact mathematical basis for degree of curve conversion (18,000/pi)
  - Remove freeway-specific design guidance, which is off topic here
  - Replace contents of Tables 3-2.03A and 3-2.03B with revised criteria from Technical Memo No. 12-11-TS-05

Section 3-3 SUPERELEVATION

- 3-3.01 General Criteria
  - Add second paragraph containing AASHTO methods explanation (replacing last sentence of 4th paragraph)
  - Revise per MnDOT re-definition of low-speed / high-speed design speed threshold
  - Various editorial wordsmithing
  - Explicitly call out Methods 2 and 5 as bases for MnDOT criteria
    - Add description of Method 5 in terms of the driver experience, particularly its emphasis on driver comfort
- 3-3.02 Rates
  - Update the maximum superelevation rate to 8%
  - Expand 1st paragraph to state basic concepts of the revised superelevation approach established in Technical Memo No. 12-11-TS-05
  - Various editorial wordsmithing
  - Expand normal crown discussion to include mention of adverse side friction as well as reference to new Table 3-3.02B
  - Remove reference to omitted old Figure 3-3.02A
  - Add paragraph to carry over criteria and guidance from Technical Memo No. 12-11-TS-05
    - Inherent approximate and therefore flexible nature of the design values
    - Example circumstances wherein flexibility is appropriate or necessary
    - Reference to Figure 3-3.02A (old Figure 3-3.03A)
  - Remove reference to omitted old Table 3-3.02B
  - Re-characterize low-speed urban superelevation figure as presenting a mathematical relationship rather than strict design values for application
  - Include 35 mph as a design speed to which numbered bulleted guidance is applicable (i.e. less than 40 mph)
  - Add information on safety effects of flexibility with superelevation on low-speed urban streets
  - Soften Bullet 1 to provide some flexibility
  - Remove verbiage in Bullet 4 directing investigation by district traffic engineers
  - Delete example calculation pertaining to guidance in numbered bullets
  - Replace Tables 3-3.02A with revised content from Technical Memo No. 12-11-TS-05
    - Do not re-introduce 'L" columns (which there is no room for)
    - Remove superelevation runoff and runout calculation criteria and maximum transition rates, all of which is covered in 3-3.03
  - Remove old Figure 3-3.02A, which had been left out of Technical Memo No. 12-11-TS-05

    - Repurpose Table 3-3.02B as a new table conveying the limit of curvature for normal crown
        - Old table had been left out of Technical Memo No. 12-11-TS-05
    - Rename 3-3.03A as Figure 3-3.02A and move earlier in the chapter in order to be referenced in this section
    - Replace Figure 3-3.02B with updated figure from Technical Memo No. 12-11-TS-05
- 3-3.03 Superelevation Transition
    - Revise maximum transition rates to adopt more flexible values in the new Green Book (2018)
    - Various editorial wordsmithing
    - Bullet 3: update computations using revised 1:200 restrictive rotation rate
    - Bullet 5: update figure reference
    - Bullet 7: remove reference to deleted values from Table 3-3.02A
- 3-3.04 Axis of Rotation
    - Bullet 3: update figure reference
- 3-3.05 Shoulder Superelevation
    - Various editorial wordsmithing
    - Bullet 1:
        - Reference and echo revised verbiage in Chapter 4
        - Add references for ramp and bridge design practice
    - Bullet 2:
        - Remove superfluous curb qualification
        - Clarify low-side design practice, borrowing verbiage from revised Chapter 4
    - Bullet 3:
        - Update cross slope break maximum
- 3-3.06 Right and Left Turn Lanes
    - Bullet 2: update maximum cross slope break based on revised criteria
        - Add sub-bullets providing more detailed guidance and criteria
    - Delete Bullet 3 to reflect revised design criteria
- The remaining sheets of 3-3 are included because they were re-numbered.

Section 6-3 RAMP DESIGN

- 6-3.04.01 Design Speed
    - Various editorial wordsmithing
    - Rewrite 1st paragraph to better convey:
        - Right sizing of design speed
        - Portion of the ramp to which design speed applies
        - General approach for different portions of ramps in various interchange configurations
    - Expand 2nd paragraph and bullets with additional information
        - Bullet 1:
            - Clarify configurations to which guidance applies
            - Discourage high-range design speeds on reverse-curving ramps
        - Bullet 2: revamp loop design speed criteria to align with AASHTO and not require or encourage overly large designs
            - Assert 250-ft radius (30 mph) loops as a practical maximum
        - Bullet 3: Expand to apply to outer connections
        - Bullet 4:
            - Suggest mainline highway design speed selection approach for connections of high importance or demand
    - Delete last paragraph and replace with discussion of general approach to ramp superelevation application
    - Table 6-3.04A: revise two values to match the AASHTO Green Book
- 6-3.04.02 Horizontal Alignment
    - Add equivalent metric rates
- 6-3.04.03 Vertical Alignment
    - Rearrange gradient tables to place U.S. Customary first

3-2.02.05 Broken-Back Curves

A broken-back curve is a curve that contains a tangent of less than 1000 ft (300 m) between two curves in the same direction. Because this type of curve violates driver expectancy and is unpleasant in appearance, it should be avoided by substituting a single longer curve where practical.

3-2.03 Superelevation and Side Friction

When moving on a circular path, a vehicle is subject to centrifugal force that acts away from the center of the curve. Vehicle weight, roadway superelevation, and side friction between the tires and the roadway counterbalance this force. If the vehicle is not skidding, all forces are in equilibrium as the following equation represents.

$$\frac{0.067V^2}{R} = \frac{V^2}{15R}$$

$$e + f = \frac{v^2}{gR} = \frac{0.067V^2}{R} = \frac{V^2}{15R} \quad \text{(U.S. Customary)}$$

$$e + f = \frac{v^2}{gR} = \frac{0.0079V^2}{R} = \frac{V^2}{127R} \quad \text{(Metric)}$$

Where:

e = rate of superelevation, ft/ft (m/m)
f = side friction factor
v = vehicle speed, ft/s (m/s)
V = vehicle speed, mph (km/h)
g = gravitational constant 32.2 ft/s^2 (9.81 m/s^2)
R = radius of curve, ft (m)

Because of winter icing conditions in Minnesota, the maximum permissible superelevation rate for design is 0.08 (ft/ft, m/m) for rural and high-speed urban facilities. To limit the complications that superelevation creates for yard drainage and driveway grades in developed areas, superelevation rates for low-speed urban streets are limited to 0.04.

Tables 3-2.03A and B list maximum side friction factors (f) for the range of roadway types as indicated. They are based on a reasonable threshold of discomfort for the vast majority of drivers and provide a generous margin against skidding, even with wet pavement and poor tire condition. Drivers, through conditioning, have a higher threshold of discomfort on low-speed urban streets; for that reason, higher maximum side friction factors are used for those facilities.

3-2.04 Maximum Degree (Minimum Radius) of Horizontal Curvature

Once the limiting values of superelevation and side friction have been determined, the maximum degree (minimum radius) of horizontal curvature can be computed for the range of design speeds. Tables 3-2.03A and B list design speeds, maximum side friction factors, and associated maximum degrees of curve and minimum curve radii based on e_{max} = 0.08 (ft/ft, m/m). Because crash frequency increases on curves as the degree of curve increases and the radius decreases, the use of minimum radii / maximum degrees of curvature should be infrequent, to the extent practical, on road segments. (Sight distances may also be affected by curve radius; refer to 3-2.05.)

The minimum radius of curvature can be calculated with the following formula.

$$R_{min} = \frac{V^2}{15(e_{max}+f_{max})}$$ (U.S. Customary)

$$R_{min} = \frac{V^2}{127(e_{max}+f_{max})}$$ (Metric)

Where:

R_{min} = minimum radius, ft (m)
V = vehicle speed, mph (km/h)
e_{max} = maximum superelevation rate of curve, ft/ft (m/m)
f_{max} = maximum side friction

The radius of curvature can be converted to the degree of curve (U.S. Customary only) by:

$$D = \frac{18{,}000}{\pi R} = \frac{5729.578}{R}$$ (U.S. Customary)

Where:

D = degree of curvature, $(^{o})$
R = radius, (ft)

Table 3-2.03A (U.S. Customary)
LIMITING VALUES OF f AND THE ASSOCIATED MAXIMUM CURVATURE
Rural and High-Speed Urban Roadways, e_{max} = 0.08 ft/ft

Design Speed (mph)	Limiting Value of Friction Factor f	Minimum Radius (ft) (rounded) $R = \frac{V^2}{15(e+f)}$	Maximum Degree of Curve (rounded) D_c
30	0.1600	250	22° 30'
35	0.1550	350	16° 15'
40	0.1500	465	12° 20'
45	0.1450	600	9° 30'
50	0.1400	760	7° 30'
55	0.1300	960	5° 55'
60	0.1200	1200	4° 45'
65	0.1100	1500	3° 50'
70	0.1000	1850	3° 05'
75	0.0900	2250	2° 35'

Table 3-2.03A (Metric)
LIMITING VALUES OF f AND THE ASSOCIATED MINIMUM RADII
Rural and High-Speed Urban Roadways, e_{max} = 0.08 m/m

Design Speed (km/h)	Limiting Value of Friction Factor f	Minimum Radius (m) (rounded) $R = \frac{V^2}{127(e+f)}$
50	0.1589	82.5
60	0.1527	125
70	0.1465	170
80	0.1403	230
90	0.1282	310
100	0.1157	405
110	0.1033	520
120	0.0909	665

Table 3-2.03B (U.S. Customary)
LIMITING VALUES OF f AND THE ASSOCIATED MAXIMUM CURVATURE
Low-Speed Urban Roadways, e_{max} = 0.04 ft/ft

Design Speed (mph)	Limiting Value of Friction Factor f	Minimum Radius (ft) (rounded) $R = \frac{V^2}{15(e+f)}$	Maximum Degree of Curve (rounded) D_c
20	0.300	78.5	73° 00'
25	0.252	145	40° 00'
30	0.221	230	24° 30'
35	0.197	345	16° 30'
40	0.178	490	11° 40'
45	0.163	665	8° 35'

Table 3-2.03B (Metric)
LIMITING VALUES OF f AND THE ASSOCIATED MINIMUM RADII
Low-Speed Urban Roadways, e_{max} = 0.04 m/m

Design Speed (km/h)	Limiting Value of Friction Factor f	Minimum Radius (m) (rounded) $R = \frac{V^2}{127(e+f)}$
30	0.312	20.5
40	0.252	43.5
50	0.214	77.5
60	0.186	125
70	0.158	195

3-3.0 SUPERELEVATION

3-3.01 General Criteria

Superelevation, a roadway cross-slope rate designated “e,” is an integral part of the design of horizontal curvature that allows a vehicle to safely and comfortably navigate through curves at higher speeds than would otherwise be possible. The sharper the curve, the steeper the rate of superelevation required.

As discussed in Section 3-2.03, adopted maximum values of e and side friction factor, “f,” establish the maximum curvatures / minimum radii associated with each design speed. For the range of curvatures between tangent alignment (no curvature, no superelevation) and minimum radii (maximum curvature, maximum superelevation), it is necessary to determine intermediate superelevation rates that balance e and f in some logical way. AASHTO has established five standard methods of distributing e and f based on varied assumptions and objectives. See AASHTO’s *A Policy on Geometric Design of Highways and Streets* for detailed explanations and derivations of these methods.

Greater side friction factors and different distributions of friction and superelevation are used for low-speed urban streets (design speed below 50 mph (80 km/h)) than for rural and high-speed urban facilities.

For low-speed urban streets, AASHTO Method 2 is used to sustain lateral acceleration. In this method, a vehicle traveling at the design speed has all centrifugal force counteracted by side friction on curves up to that requiring the maximum, f_{max}. For sharper curves, f remains at f_{max}, and e is used in direct proportion to the continued increase in curvature until e reaches its maximum, e_{max}.

On all other roadways, Method 5 is used. In this distribution, side friction and superelevation both increase gradually for increasing rates of curvature until f_{max} and e_{max} are reached simultaneously. With this method, most of the lateral acceleration is sustained by superelevation in flatter curves, with side friction counteracting an increasing amount of lateral acceleration in sharper curves.

The rationale for these different approaches is that drivers, through conditioning, have a higher threshold of discomfort when reacting to centrifugal force on horizontal curves on low-speed streets than on rural and high-speed facilities. Superelevation is thereby minimized in built-up urban areas, allowing simpler intersection designs, yard drainage, and driveway entrances. On rural and high-speed highways (design speeds 50 mph (80 km/h) or higher), the prescribed approach prioritizes driver comfort, which reduces cumulative strain on longer trips.

3-3.02 Rates

The maximum allowable rate of superelevation in Minnesota is 0.08 (ft/ft, m/m), which AASHTO characterizes as a logical maximum where ice and snow are factors in design. Historically, however, Minnesota has used a 0.06 maximum rate. To provide system-wide consistency, the design values herein use $e_{max} = 0.06$ as the basis for Method 5 distributions, but they also provide flexibility to use up to a 0.08 superelevation rate where sharper curves are necessary and/or additional superelevation is judged desirable or beneficial. Maximum curvatures / minimum radii based on the 0.08 maximum rate may be applied even where superelevation greater than 0.06 is not used. In most cases, superelevation rates exceeding 0.06 should be avoided on urban and suburban facilities or where slow-moving vehicles are expected to be common.

Table 3-3.02A shows the superelevation rates for rural and high-speed roadways based on the approach and discretionary flexibility explained above. For very flat curvature, the normal crown is maintained throughout the curve, with a small amount of adverse side friction considered tolerable. This is denoted by “NC” in the table. Table 3-3.02B provides the exact maximum curvatures (minimum radii) for use with a normal crown as well as the associated adverse friction factors. As the curvature becomes slightly sharper, it is sufficient to superelevate the highway at the normal cross slope rate so that the highway is superelevated in a plane sloping in one direction across the entire cross section. Table 3-2.02A denotes this situation as “RC,” or remove crown.

The design superelevation rates in Table 3-3.02A are based on various approximations including a point-mass physical model and an assumed threshold of driver comfort. They should therefore be considered flexible in nature. As noted in 3-2.03, the maximum side friction factors provide a generous margin against skidding even in non-ideal circumstances, and the tabular values yield some fraction of those maximums. The AASHTO *Highway Safety Manual* indicates no known safety effect of superelevation rates that deviate from these values by as much as 0.01 (ft/ft, m/m). Departure from the tabular values may be appropriate in a variety of circumstances, most notably intersections and the approaches to intersections, where superelevation tends to complicate grades and drainage and can create sight distance deficits. Additionally, where a pedestrian access route crosses a roadway (i.e. a crosswalk), a superelevation rate exceeding 0.05 is not permitted due to Americans with Disabilities Act (ADA) requirements. In any cases where less than the tabular values are contemplated or necessary, refer to Figure 3-3.02A, which indicates maximum curvatures / minimum radii associated with maximum rural and high-speed friction factors. If a resulting condition exceeds the maximum f for the design speed, an advisory speed posting may be recommended.

Figure 3-3.02B shows the relationship between superelevation rates and curve radii based on low-speed urban friction factors and the Method 2 distribution, up to the maximum superelevation rate of 0.04. This applies exclusively to low-speed urban locations.

For urban streets with design speeds less than 40 mph (60 km/h), superelevation is rarely applied. Most of the time, side friction is adequate. Even if standard minimum radii or superelevation rates are not provided, there are no known data that would indicate a negative safety consequence for low-speed urban facilities. If constraints dictate the use of greater than the maximum curvature or limiting friction factor for the design speed, consider the following:

1. Preferably avoid using superelevation on curves, especially if it would create or worsen drainage problems.
2. Make sure to meet the grades of the surrounding properties, entrances, and cross streets without introducing grades on the main roadway that exceed the maximum longitudinal grade.
3. Supply sufficient transitions to and from the desired superelevation.
4. Weigh the use of superelevation and the attainable design speed against the construction effort and the local municipal practice. District Traffic Engineers may recommend an advisory posting on curves not meeting standard criteria for the selected design speed.

Table 3-3.02A (U.S. Customary)

RATE OF SUPERELEVATION FOR RURAL AND HIGH-SPEED URBAN ROADWAYS (e_{max} = 0.08 ft/ft)

DEGREE OF CURVE (D_c)	CURVE RADIUS (R)	Superelevation Rate, e (ft/ft), for Indicated Design Speed									
		30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph	65 mph	70 mph	75 mph
0° 15'	22,918	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
0° 30'	11,459	NC	NC	NC	NC	NC	NC	NC	RC	RC	RC
0° 45'	7,639	NC	NC	NC	NC	RC	RC	0.021	0.023	0.026	0.029
1° 00'	5,730	NC	NC	NC	RC	RC	0.023	0.027	0.030	0.033	0.037
1° 15'	4,584	NC	NC	RC	RC	0.024	0.028	0.032	0.036	0.040	0.044
1° 30'	3,820	NC	RC	RC	0.024	0.028	0.032	0.037	0.041	0.046	0.051
1° 45'	3,274	NC	RC	0.023	0.027	0.031	0.036	0.041	0.046	0.051	0.056
2° 00'	2,865	RC	0.021	0.025	0.030	0.035	0.040	0.045	0.049	0.055	0.059
2° 15'	2,546	RC	0.023	0.028	0.033	0.038	0.043	0.048	0.053	0.057	0.060
2° 30'	2,292	RC	0.025	0.030	0.035	0.040	0.045	0.051	0.055	0.059	(1)
2° 45'	2,083	0.021	0.027	0.032	0.037	0.042	0.048	0.053	0.058	0.060	D_{max}=2°35'
3° 00'	1,910	0.023	0.029	0.034	0.039	0.044	0.050	0.055	0.059	(1)	
3° 15'	1,763	0.025	0.030	0.036	0.041	0.046	0.052	0.057	0.060	D_{max}=3°05'	
3° 30'	1,637	0.026	0.032	0.038	0.043	0.048	0.054	0.058	(1)		
3° 45'	1,528	0.028	0.034	0.039	0.045	0.050	0.055	0.059	(1)		
4° 00'	1,432	0.029	0.035	0.041	0.046	0.051	0.057	0.060	D_{max}=3°50'		
4° 15'	1,348	0.030	0.036	0.042	0.048	0.053	0.058	0.060			
4° 30'	1,273	0.031	0.038	0.043	0.049	0.054	0.059	(1)			
4° 45'	1,206	0.033	0.039	0.044	0.050	0.055	0.059	(1)			
5° 00'	1,146	0.034	0.040	0.046	0.051	0.056	0.060	D_{max}=4°45'			
5° 15'	1,091	0.035	0.041	0.047	0.053	0.057	0.060				
5° 30'	1,042	0.036	0.042	0.048	0.054	0.058	(1)				
5° 45'	996	0.037	0.043	0.049	0.055	0.059	(1)				
6° 00'	955	0.038	0.044	0.050	0.055	0.059	D_{max}=5°55'				
6° 15'	917	0.038	0.045	0.051	0.056	0.060					
6° 30'	881	0.039	0.045	0.052	0.057	0.060					
6° 45'	849	0.040	0.046	0.053	0.058	0.060					
7° 00'	819	0.041	0.047	0.053	0.058	(1)					
7° 15'	790	0.041	0.048	0.054	0.059	(1)					
7° 30'	764	0.042	0.049	0.055	0.059	(1)					
7° 45'	739	0.043	0.049	0.055	0.059	D_{max}=7°30'					
8° 00'	716	0.043	0.050	0.056	0.060						
8° 15'	694	0.044	0.051	0.057	0.060						
8° 30'	674	0.045	0.051	0.057	0.060						
8° 45'	655	0.045	0.052	0.058	(1)						
9° 00'	637	0.046	0.053	0.058	(1)						
9° 15'	619	0.046	0.053	0.058	(1)						
9° 30'	603	0.047	0.054	0.059	(1)						
9° 45'	588	0.047	0.054	0.059	D_{max}=9°30'						
10° 00'	573	0.048	0.055	0.059							
10° 30'	546	0.049	0.056	0.060							
11° 00'	521	0.050	0.057	0.060							
11° 30'	498	0.051	0.057	(1)							
12° 00'	477	0.052	0.058	(1)							
12° 30'	458	0.053	0.059	D_{max}=12°20'							
13° 00'	441	0.054	0.059								
13° 30'	424	0.054	0.060								
14° 00'	409	0.055	0.060								
14° 30'	395	0.056	0.060								
15° 00'	382	0.056	0.060								
16° 00'	358	0.058	(1)								
17° 00'	337	0.058	D_{max}=16°15'								
18° 00'	318	0.059									
19° 00'	302	0.060									
20° 00'	286	0.060									
20° 50'	275	0.060									
22° 55'	250	(1)									
		R_{min}=250'									

KEY TO TABLE

R_{min}	Minimum radius of curve
D_{max}	Maximum degree of curve
NC	Normal Crown
RC	Remove Crown

NOTES:

(1) Superelevation rate from 0.06 to 0.08 ft/ft may be used at the designer's discretion. Refer to 3-3.02 for background and guidance.

Table 3-3.02A (Metric)

RATE OF SUPERELEVATION FOR RURAL AND HIGH-SPEED URBAN ROADWAYS (e_{max} = 0.08 m/m)

CURVE RADIUS (R)	Superelevation Rate, e (m/m), for Indicated Design Speed							
	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h
5,000	NC	NC	NC	NC	NC	NC	NC	NC
3,000	NC	NC	NC	NC	NC	RC	RC	RC
2,500	NC	NC	NC	NC	RC	RC	0.023	0.027
2,000	NC	NC	NC	RC	0.021	0.025	0.029	0.033
1,500	NC	NC	RC	0.022	0.027	0.032	0.036	0.042
1,200	NC	RC	0.022	0.027	0.032	0.038	0.043	0.050
1,000	RC	0.021	0.026	0.031	0.036	0.043	0.049	0.055
900	RC	0.023	0.028	0.034	0.039	0.046	0.052	0.058
800	RC	0.025	0.031	0.036	0.042	0.049	0.055	0.060
750	RC	0.026	0.032	0.038	0.044	0.051	0.057	(1)
700	0.021	0.028	0.034	0.040	0.046	0.053	0.058	(1)
650	0.023	0.029	0.036	0.042	0.048	0.054	0.059	R_{min} = 665 m
600	0.024	0.031	0.038	0.043	0.050	0.056	0.060	
550	0.026	0.033	0.040	0.046	0.052	0.058	(1)	
500	0.028	0.035	0.042	0.048	0.055	0.059	R_{min} = 520 m	
475	0.029	0.036	0.043	0.049	0.056	0.060		
450	0.030	0.037	0.044	0.050	0.057	0.060		
425	0.031	0.039	0.045	0.052	0.058	(1)		
400	0.033	0.040	0.047	0.053	0.059	R_{min} = 405 m		
375	0.034	0.041	0.048	0.055	0.060			
350	0.035	0.043	0.050	0.056	0.060			
325	0.037	0.044	0.052	0.058	(1)			
300	0.039	0.046	0.053	0.059	R_{min} = 310 m			
275	0.040	0.048	0.055	0.060				
250	0.042	0.050	0.057	(1)				
240	0.043	0.051	0.058	(1)				
230	0.044	0.052	0.058	(1)				
220	0.045	0.053	0.059	R_{min} = 230 m				
210	0.046	0.054	0.059					
200	0.047	0.055	0.060					
190	0.048	0.056	(1)					
180	0.049	0.057	(1)					
170	0.050	0.058	(1)					
160	0.052	0.059	R_{min} = 170 m					
150	0.053	0.059						
140	0.054	0.060						
130	0.056	(1)						
125	0.057	(1)						
120	0.057	R_{min} = 125 m						
115	0.058							
110	0.059							
105	0.059							
100	0.060							
95	0.060							
90	(1)							
85	(1)							
	R_{min} = 82.5 m							

KEY TO TABLE

R_{min} Minimum radius of curve
NC Normal Crown
RC Remove Crown

NOTES:

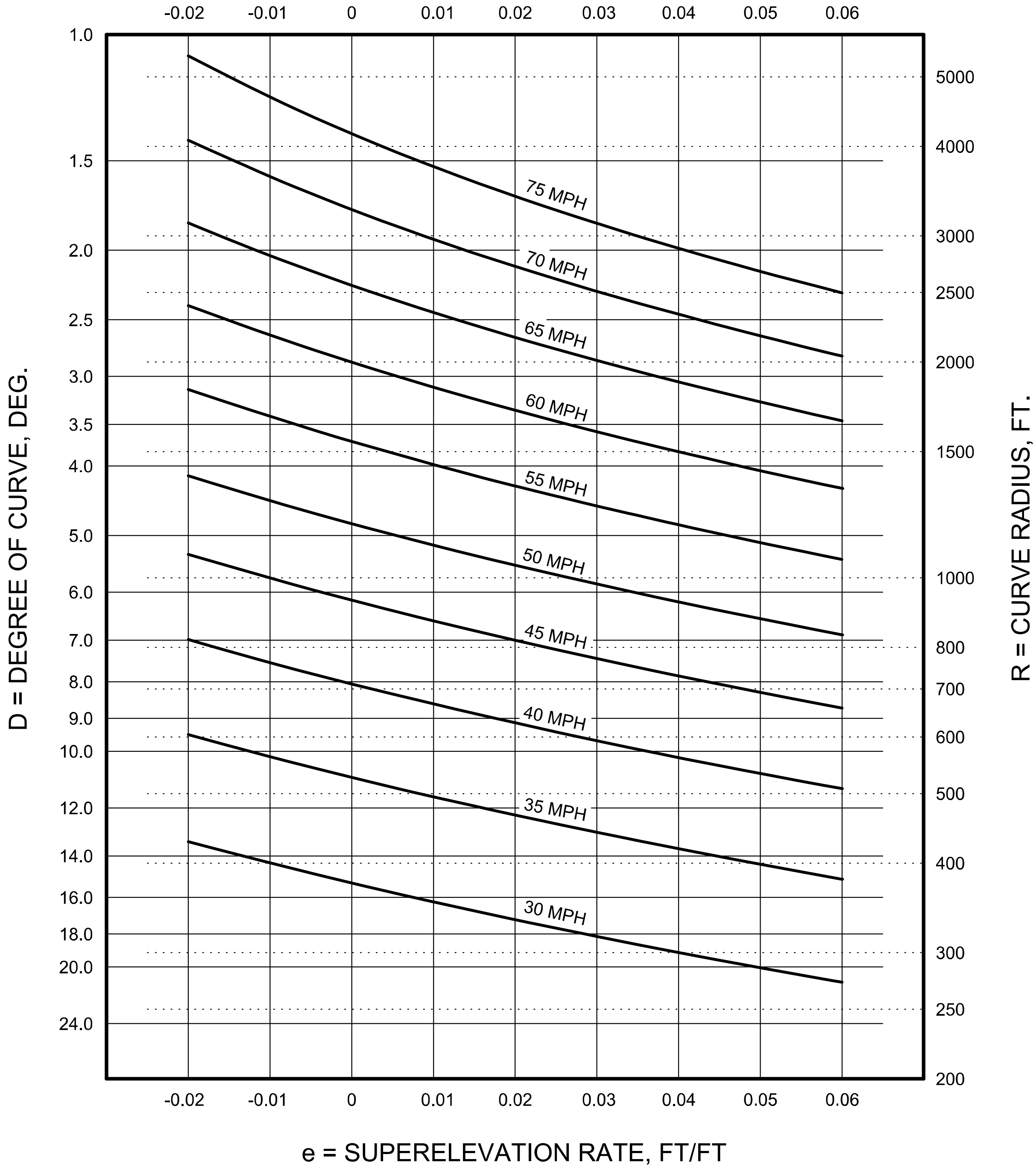
(1) Superelevation rate from 0.06 to 0.08 m/m may be used at the designer's discretion. Refer to 3-3.02 for background and guidance.

Table 3-3.02B (U.S. Customary)
MAXIMUM CURVATURE FOR NORMAL CROWN SECTION
Rural and High-Speed Urban Roadways

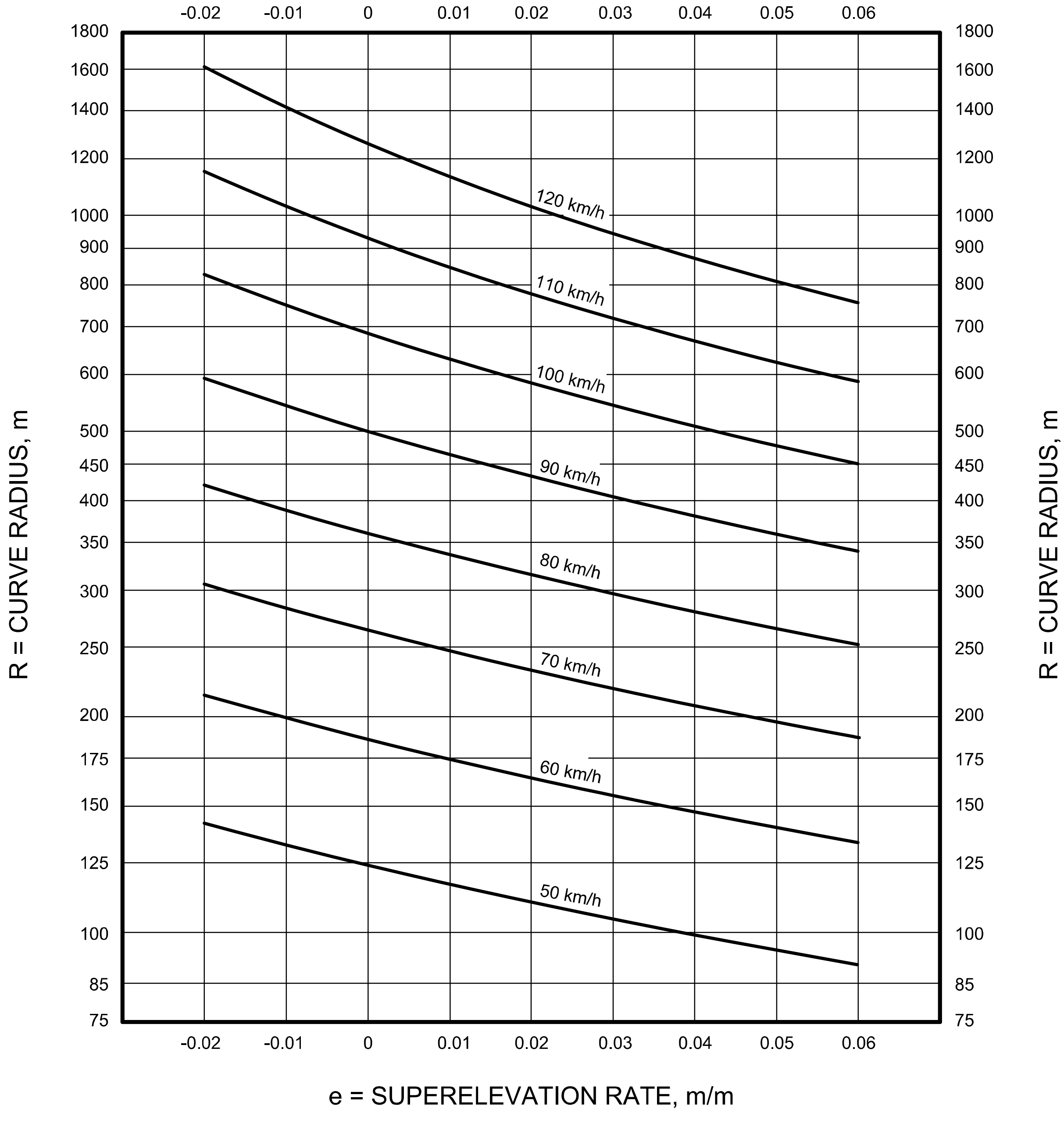
Design Speed, mph	Maximum Degree Of Curve	Minimum Curve Radius, ft	Incurred Adverse Side Friction Factor (f)	
			0.015 Normal Cross Slope	0.02 Normal Cross Slope
30	1º 49'	3,150	0.034	0.039
35	1º 23'	4,130	0.035	0.040
40	1º 05'	5,250	0.035	0.040
45	0º 52.5'	6,500	0.036	0.041
50	0º 43.4'	7,890	0.036	0.041
55	0º 36.3'	9,430	0.036	0.041
60	0º 30.6'	11,100	0.037	0.042
65	0º 27.3'	12,500	0.037	0.042
70	0º 24.3'	14,000	0.038	0.043
75	0º 21.6'	15,700	0.039	0.044

Table 3-3.02B (Metric)
MINIMUM RADIUS FOR NORMAL CROWN SECTION
Rural and High-Speed Urban Roadways

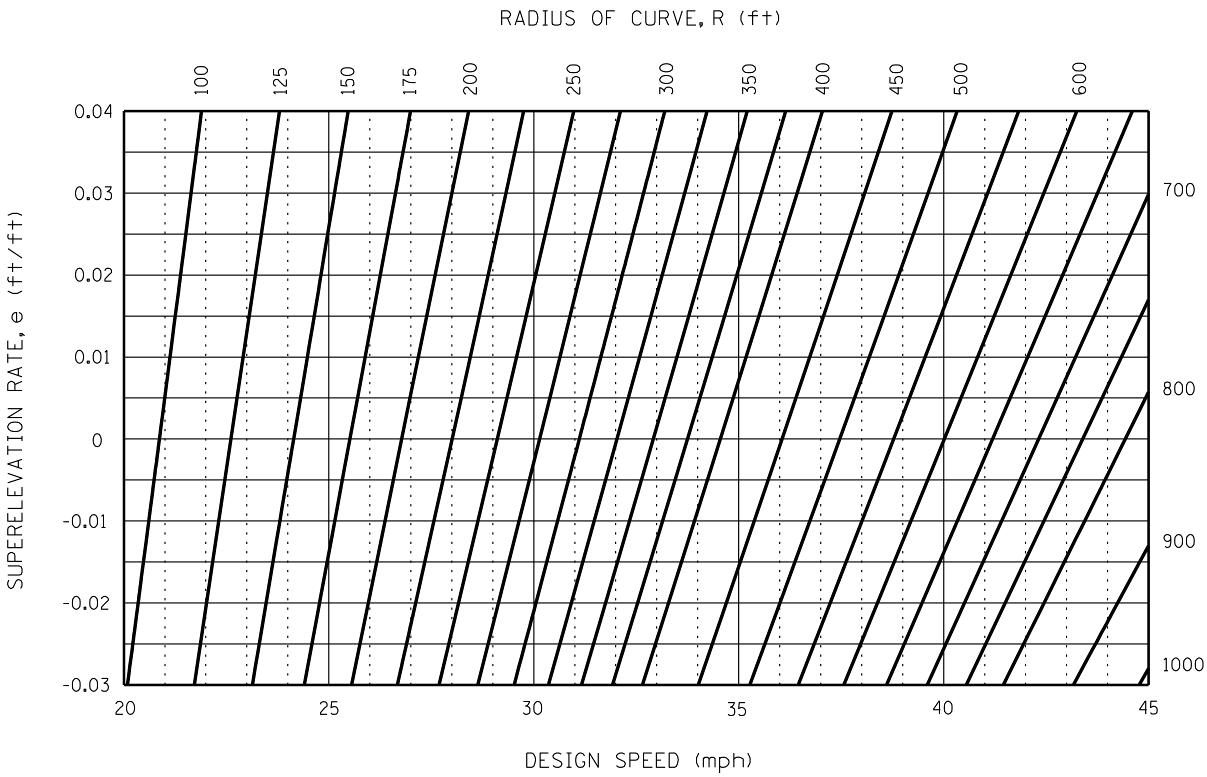
Design Speed, km/h	Minimum Curve Radius, m	Incurred Adverse Side Friction Factor (f)	
		0.015 Normal Cross Slope	0.02 Normal Cross Slope
50	1,050	0.034	0.039
60	1,440	0.035	0.040
70	1,900	0.035	0.040
80	2,360	0.036	0.041
90	2,870	0.037	0.042
100	3,520	0.037	0.042
110	4,080	0.038	0.043
120	4,770	0.039	0.044



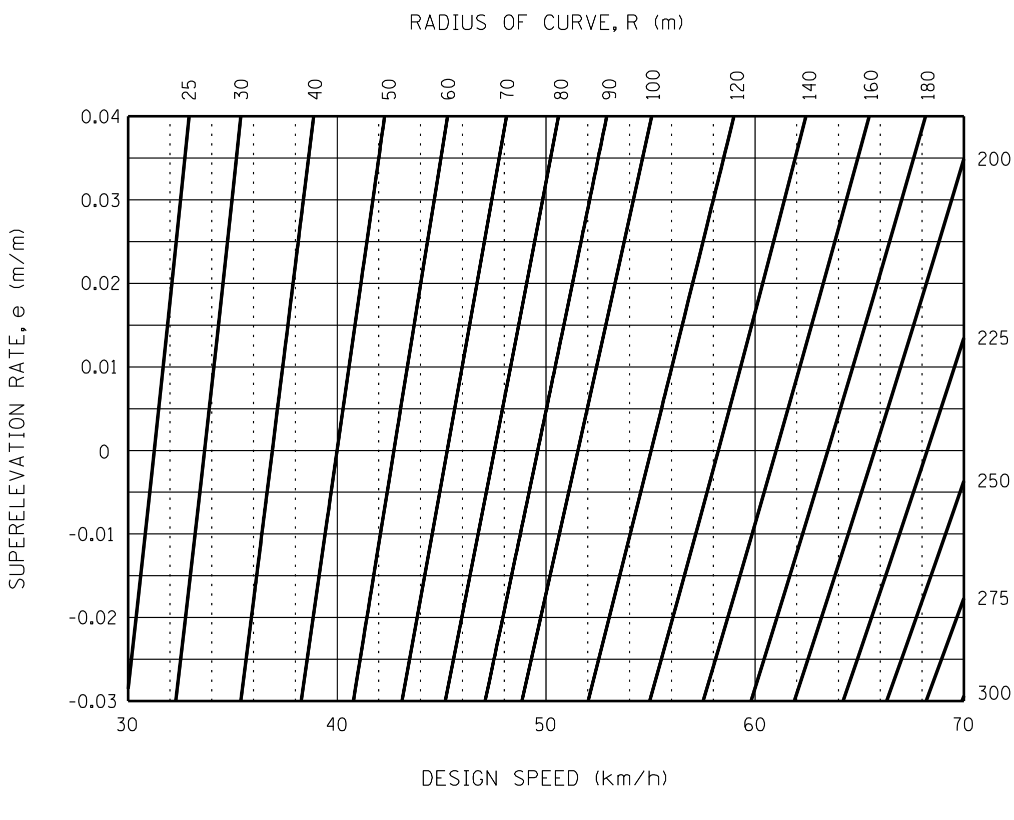
MAXIMUM SPEED ON HORIZONTAL CURVES
BASED ON MAXIMUM (RURAL) FRICTION FACTORS
For special designs in restrictive conditions
Figure 3-3.02A (U.S. Customary)



MAXIMUM SPEED ON HORIZONTAL CURVES
BASED ON MAXIMUM (RURAL) FRICTION FACTORS
For special designs in restrictive conditions
Figure 3-3.02A (Metric)



SUPERELEVATION RATES FOR LOW-SPEED URBAN STREETS
Figure 3-3.02B (U.S. Customary)



SUPERELEVATION RATES FOR LOW-SPEED URBAN STREETS
Figure 3-3.02B (Metric)

3-3.03 Superelevation Transition

To meet the requirements of comfort and safety, superelevation should be introduced and removed uniformly over the length adequate for the likely travel speeds. The total length of the transition is a function of the amount of superelevation, the width of the pavement, and the rate of transition. The design factors to consider when developing superelevation are listed below:

1. Tangent runout is a gradual change from a normal crown section to a point where the adverse cross slope of the lane (or lanes) on the outside of the curve has been removed and that portion of the cross section is level. The removal rate is usually the same as the superelevation runoff rate.
2. Superelevation runoff is a gradual change from the end of the tangent runout to a cross section that is fully superelevated. The transition rate is the relative gradient (slope) between an edge of pavement or a lane line of rotation, and the axis of rotation, also known as the "hip point," which is usually the profile grade location. The desirable rate of transition is 1:400 for most two-lane highways and other roads where a two-lane pavement is rotated about the centerline. Where conditions are restrictive, a 1:400 transition rate may not be practical. In these cases the following values may be used as maximums for one lane of rotation: 1:125 for 20 mph (30 km/h); 1:150 for 30 mph (50 km/h); 1:175 for 40 mph (70 km/h); 1:200 for 50 mph (80 km/h) and greater. These values result in a more abrupt rollover and will not be as aesthetically pleasing as a 1:400 but are considered tolerable for driver comfort.
3. The formulas below show computation of the lengths of the superelevation runoff and tangent runout for two-lane highways when one lane is superelevated on each side of the hip point.

   Tangent runout distance = $\frac{W \times e_{tan}}{S}$

   Superelevation runoff distance = $\frac{W \times e}{S}$

   Where:

   S = Longitudinal slope, ft/ft (m/m)
   W = Lane width (table is based on 12 ft (3.6 m)
   e_{tan} = Rate of cross slope on tangent, ft/ft (m/m)
   e = Rate of superelevation required, ft/ft (m/m)

   Example: Design speed = 60 mph (100 km/h)

   R = Radius of curve = 2625 ft (800 m)
   S = $\frac{1}{200}$ or 0.005 (ft/ft, m/m) (restrictive condition)
   W = 12 ft (3.6 m)
   e_{tan} = 0.02 (ft/ft, m/m)
   e = 0.049 (ft/ft, m/m)

   Solution: Tangent runout = 200 x 12 x 0.02 = 48.0 ft (200 x 3.6 x 0.02 = 14.40 m)

   Superelevation runoff = 200 x 12 x 0.049 = 117.6 ft (200 x 3.6 x 0.049 = 35.28 m)
4. When rotating more than one lane and/or shoulder on the same side of the hip point (as is the case on many multi-lane facilities), increase the transition lengths beyond what is required for two-lane roads. Multiply the adjustment factors in Table 3-3.03 by the prescribed value of W used in the runoff rate formula $L = \frac{W \times e}{S}$ (where W = 12 ft (3.6 m)) to determine both maximum runoff rates.
5. On simple curves, 67 percent of the superelevation runoff should normally be developed on the tangent and 33 percent on the circular curve. This ratio is a compromise between placing all the transition on the tangent section (where superelevation is not needed) and placing all the transition on the curve (where full superelevation is needed). Adjustments to this distribution may be necessary to accommodate bridge approaches or other restrictions. AASHTO suggests a range of 60 to 90 percent of the runoff placed on the tangent is acceptable. When the beginning location of superelevation is changed, use Figure 3-3.02A to determine if adequate superelevation is maintained at the point of curvature (PC) and/or point of tangency (PT) of the curve.

6. On spiral curves, the superelevation runoff transition is normally within the entire length of the spiral (TS to SC and CS to ST).
7. Where the axis of rotation for superelevation is at the median edge of pavement, as in Figure 3-3.04E, apply the computed superelevation runoff length for a four-lane divided highway.
8. Where the axis of rotation for superelevation is at the median edge of pavement for six- and eight-lane roadways, use the tangent runout and superelevation runoffs given on Figures 3-3.04F and G and vary them according to the amount of superelevation applied.
9. Chapter 4 contains information on cross sections that is relevant to the development of superelevation.

At times, the superelevation transition rate or beginning location of superelevation may need to be altered due to restrictive conditions. Some suggestions to accomplish alterations are listed below.

1. Change the size or placement of the curve.
2. Change the starting point of the transition by changing the rate of transition.
3. Move the starting point off the bridge and approach panel, changing the 67 percent / 33 percent transition split.

U.S. CUSTOMARY AND METRIC	
Number of Lanes Rotated	**Adjustment Factor**
1	1.0
2	1.5
3	2.0
4	2.5

ADJUSTMENT FACTOR FOR NUMBERS OF LANES ROTATED
Use when rotating more than one lane and/or shoulder to determine maximum runoff rates for superelevation transition.
Table 3-3.03 (Dual Unit)

3-3.04 Axis of Rotation

When superelevation is needed on a curve, the designer must establish a point on the cross section that the cross slope will gradually be rotated around to change to the specified superelevated slope. The location of this point varies with the basic characteristics of the typical section.

1. For two-lane and undivided highways, the axis of rotation should be at the crown ("hip" point) of the roadway. If control is needed, the axis may be at the edge of the outside or inside lane or gutter flow line if desired.
2. On divided highways with relatively wide depressed medians, the axis of rotation can be at the hip point of each roadway or at the edge of the lane or shoulder nearest the median of each roadway. Placing the axis at the hip point results in median edges at different elevations, but reduces the elevation differential between extreme pavement edges. If the highway will be widened in the future, it is desirable to rotate about the inside lane or shoulder.
3. On divided highways with narrow, raised medians, the axis of rotation should be at the edge of the lane or shoulder nearest the median of each roadway. If an at-grade crossing is located on the superelevated curve, the impact on intersecting traffic should be considered in selecting the axis of rotation. A special design may be necessary. Use Figure 3-3.02A to determine if adequate superelevation is provided.
4. On divided highways with concrete median barriers, the criteria presented in number 3 above will apply, but the rotation should occur at the barrier gutter, otherwise a stepped barrier may be required.

Figures 3-3.04A through G illustrate how to rotate a pavement to develop superelevation on various types of highways with their appropriate transition rates and axes of rotation. Actual cross slopes may vary by current standards or specific conditionsthat will affect the tangent runout and superelevation runoff lengths. The above criteria and the figures describe the general treatment for axis of rotation. Selecting a different axis may be desirable or necessary at specific site conditions due to drainage, grades, ground profile, or aesthetics. In these cases, use:

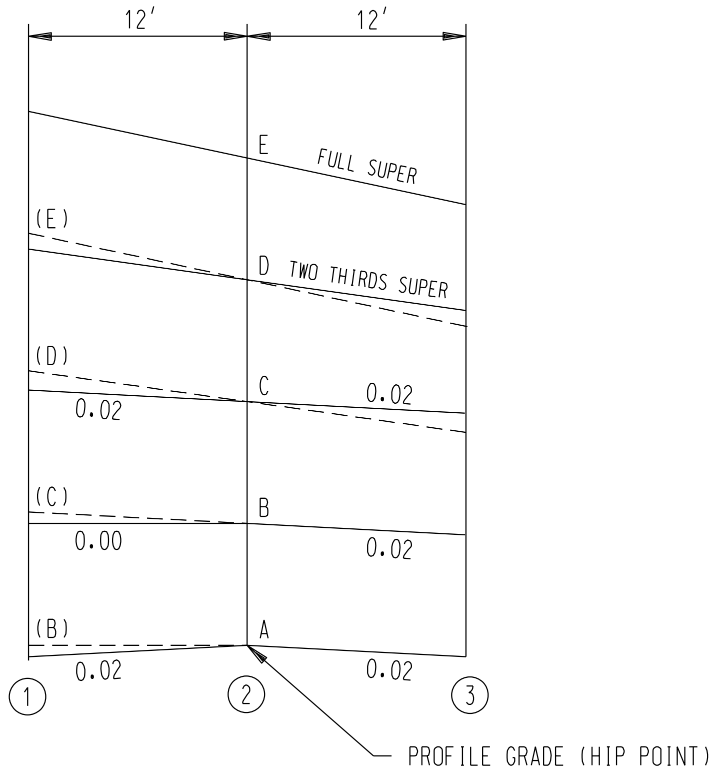
1. Figure 3-3.04A: superelevation of a two-lane highway where the axis of rotation is at the hip point;
2. Figure 3-3.04B: superelevation of a three-lane highway with horizontal curve to the right where the axis of rotation is at the hip point;
3. Figure 3-3.04C: superelevation of a three-lane highway with horizontal curve to the left where the axis of rotation is at the hip point;
4. Figure 3-3.04D: superelevation of a four-lane undivided highway where the axis of rotation is at the hip point;
5. Figure 3-3.04E: superelevation of a four-lane divided highway without inside shoulders where the axis of rotation is at the median edge of pavement;
6. Figure 3-3.04F: superelevation of a six-lane divided highway with inside shoulders where the axis of rotation is at the median edge of pavement (also see Standard Plans Manual), and;
7. Figure 3-3.04G: superelevation of an eight-lane divided highway with inside shoulders and concrete median barriers (CMB) where the axis of rotation is at the inside edge of the CMB (also see Standard Plans Manual).

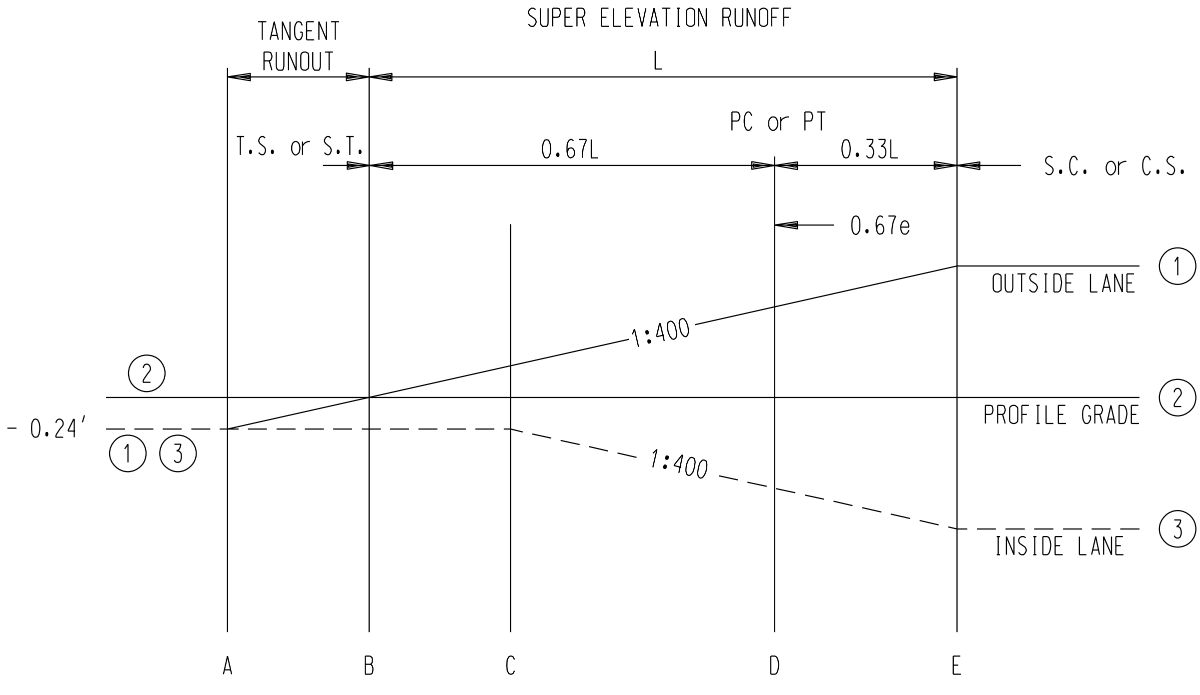
3-3.05 Shoulder Superelevation

1. As discussed in Chapter 4, shoulders generally slope away from the travel lanes, although narrow paved shoulders may slope with the adjacent lane. Shoulders on bridges and some interchange ramps will also slope with the adjacent traveled way; refer to Chapters 9 and 6 respectively.
2. On superelevated highways with shoulders, slope the high-side shoulder away from the through lanes at a minimum slope of 0.01 (ft/ft, m/m). Slope the low-side shoulder at the same rate as the through lanes where the superelevation rate exceeds the typical shoulder cross slope.
3. The algebraic difference between the through-lane slope and the high-side shoulder slope should normally not exceed 0.07. Where the travel lane superelevation rate exceeds 0.06, the algebraic difference may vary up to a standard maximum of 0.08. Refer to 4-4.01.02 for guidance on the use of non-standard cross slope breaks to accommodate superelevation rates up to 8 percent.

3-3.06 Right- and Left-Turn Lanes

1. Turn lanes on the low side of superelevated roadways should have the same cross slope as the adjacent travel lanes.
2. Turn lanes on the high side of superelevated roadways should ideally slope away from the adjacent travel lane at the normal tangent section cross slope; however, the algebraic difference between the through lane and turn lane cross slopes should be limited to 0.04 (ft/ft, m/m) desirable, 0.05 maximum.
    a. It is preferable to provide the normal tangent cross slope in the turn lane, even where it is necessary to exceed the 0.04 desirable cross slope break.
    b. The turn lane cross slope may vary to a minimum of 0.01 in order to accommodate a through-lane superelevation rate up to 0.04 (maximum cross slope break of 0.05).
    c. Superelevation rates exceeding 0.04 will typically require the high-side turn lane to slope toward the travel lanes. This is undesirable from the standpoint of surface drainage and should therefore be avoided where practical. Designers should exercise appropriate flexibility with superelevation rates in order to avoid this condition. Refer to 3-3.02 for guidance. Marginal deviation from standard rates may also be appropriate to limit the cross slope break to the 0.04 desirable maximum.





ALL SLOPES ARE IN FT/FT

SUPERELEVATION 2-LANE HIGHWAY
Axis Of Rotation At "Hip Point"

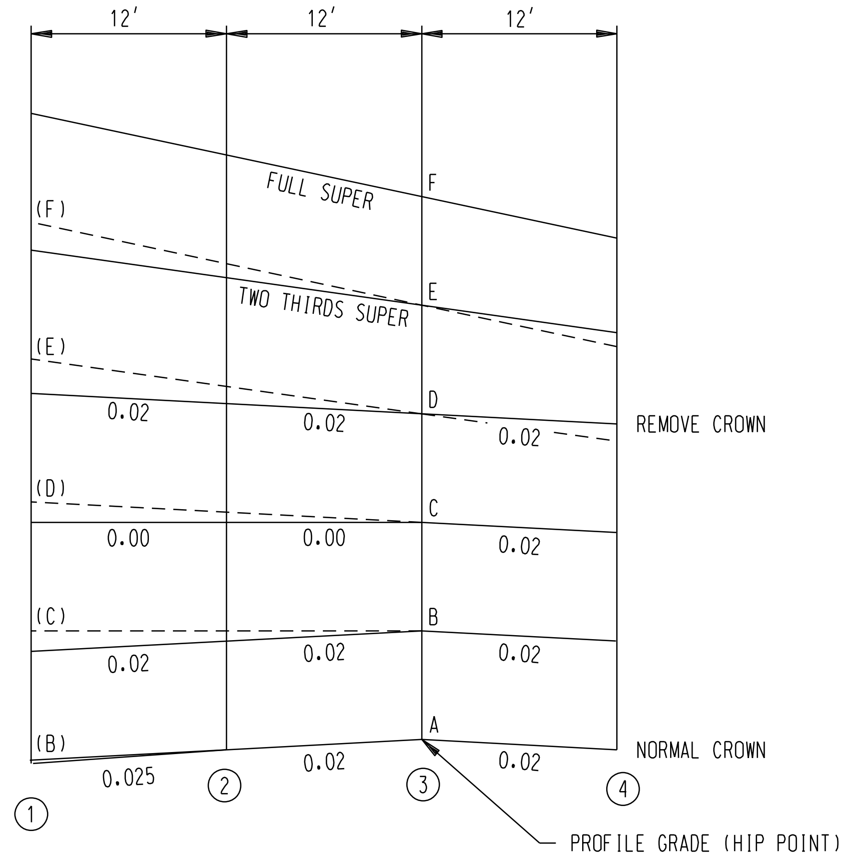
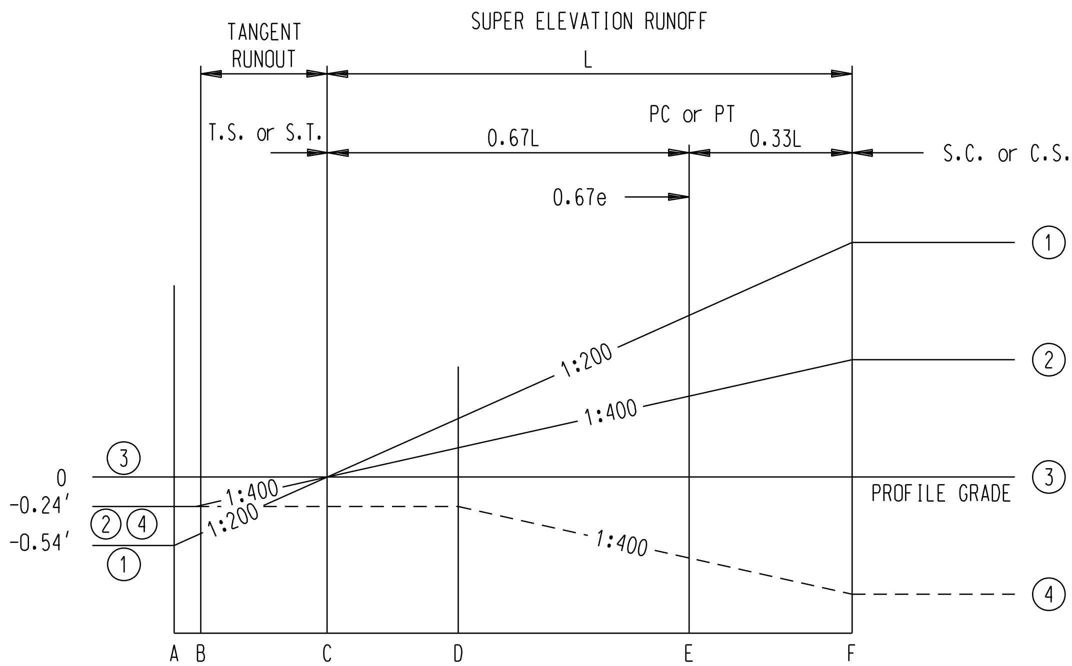
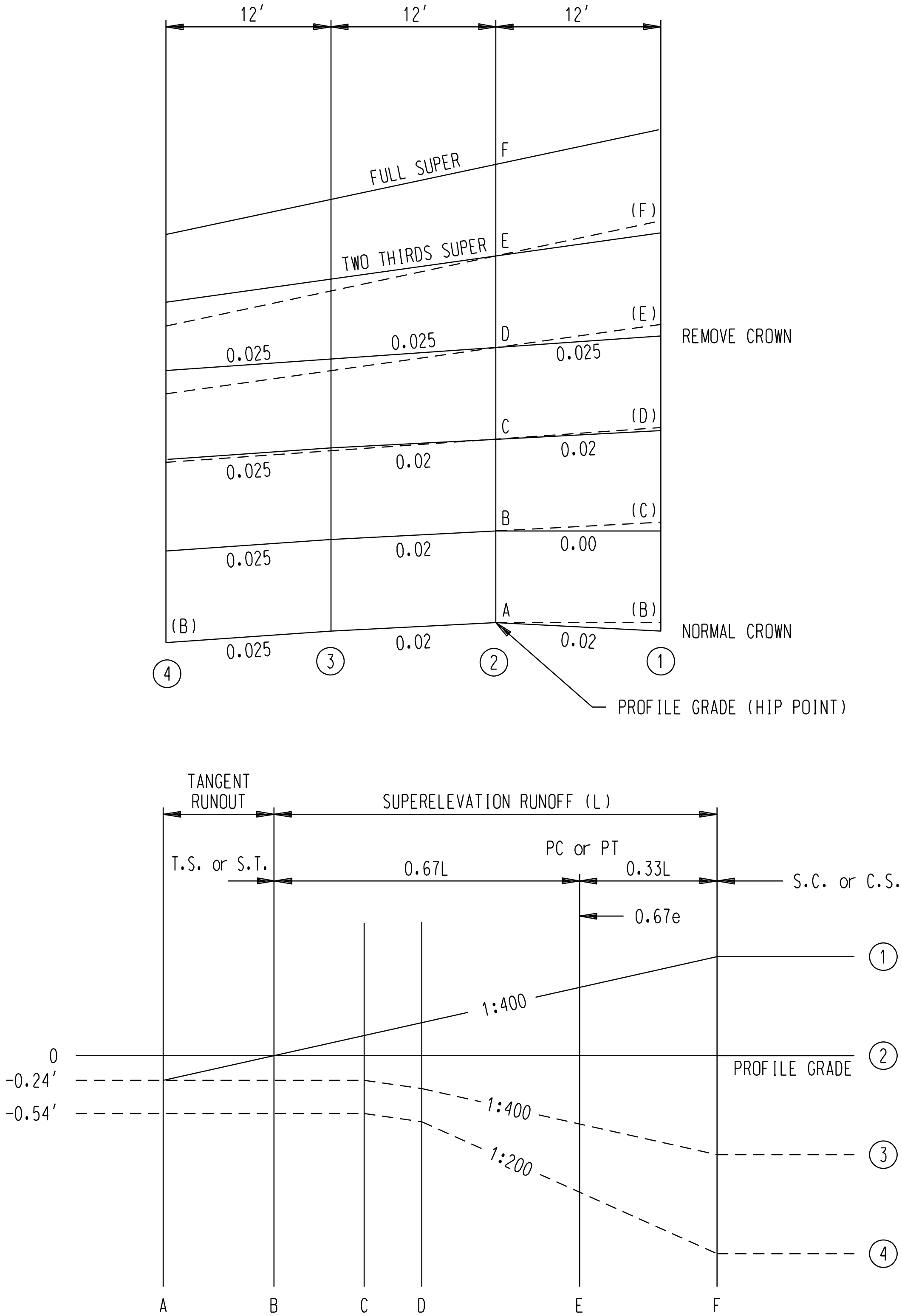


Figure 3-3.04A



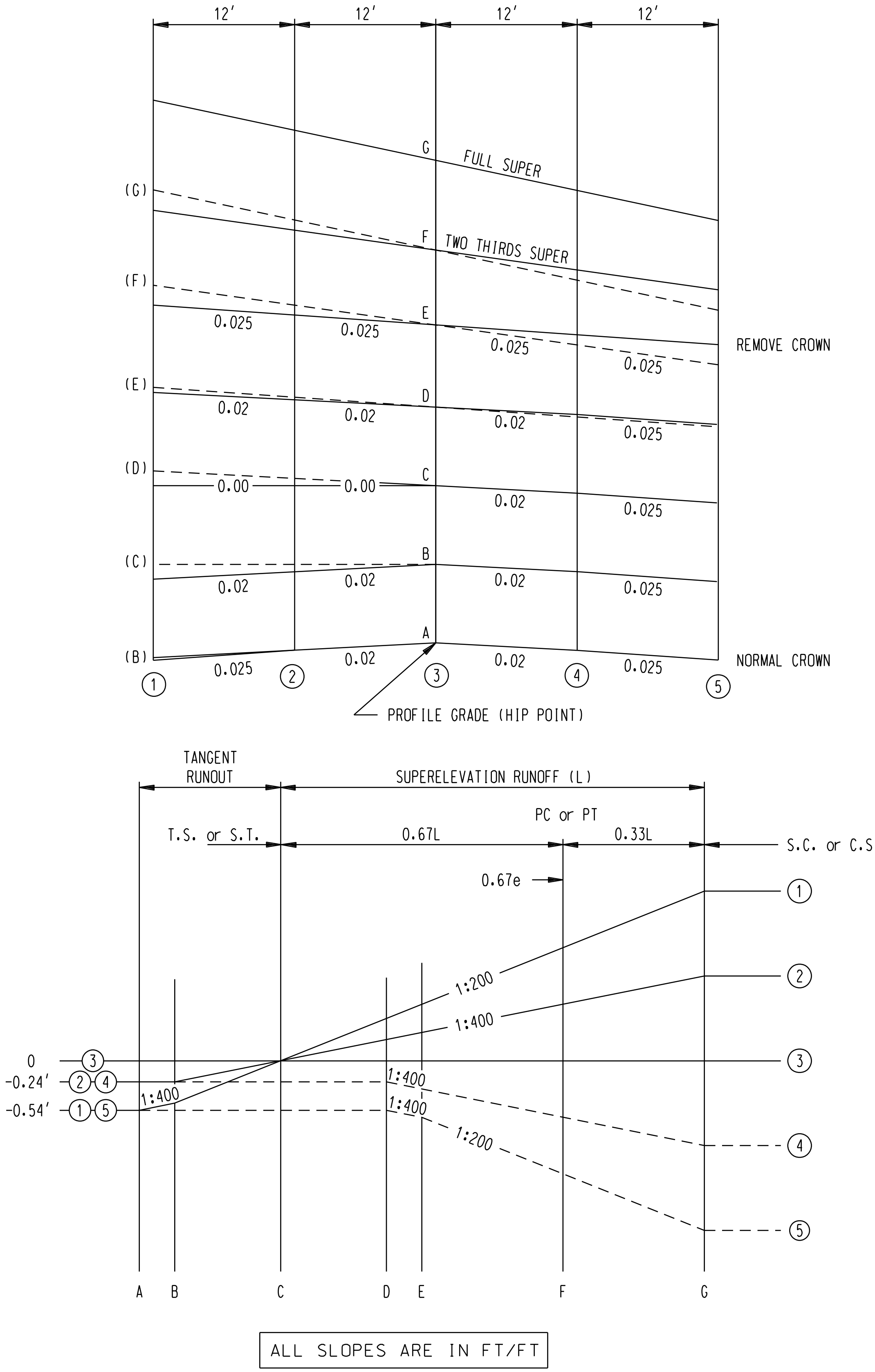
ALL SLOPES ARE IN FT/FT

SUPERELEVATION 3-LANE HIGHWAY (RIGHT)
Axis Of Rotation At "Hip Point"
Figure 3-3.04B

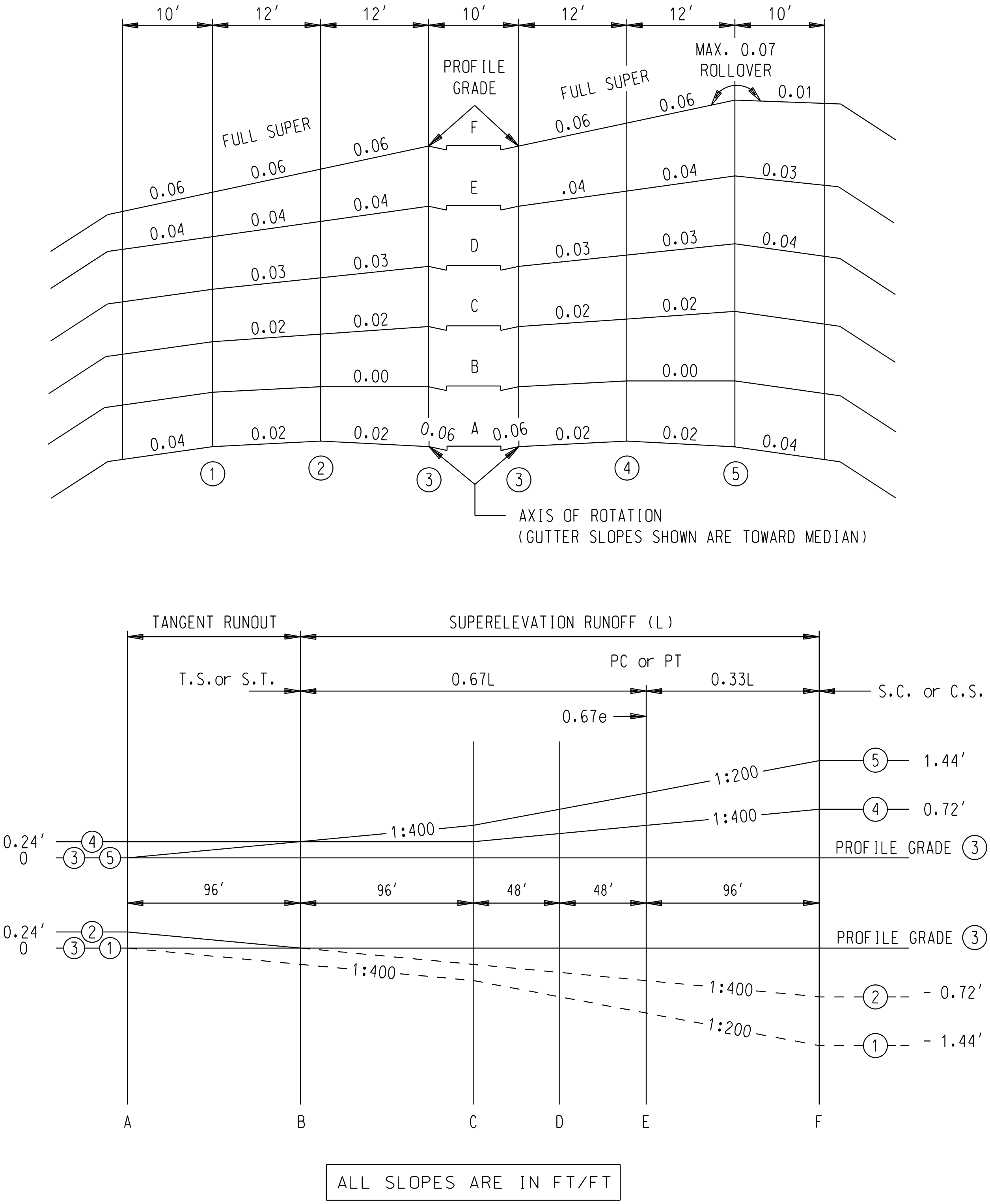


ALL SLOPES ARE IN FT/FT

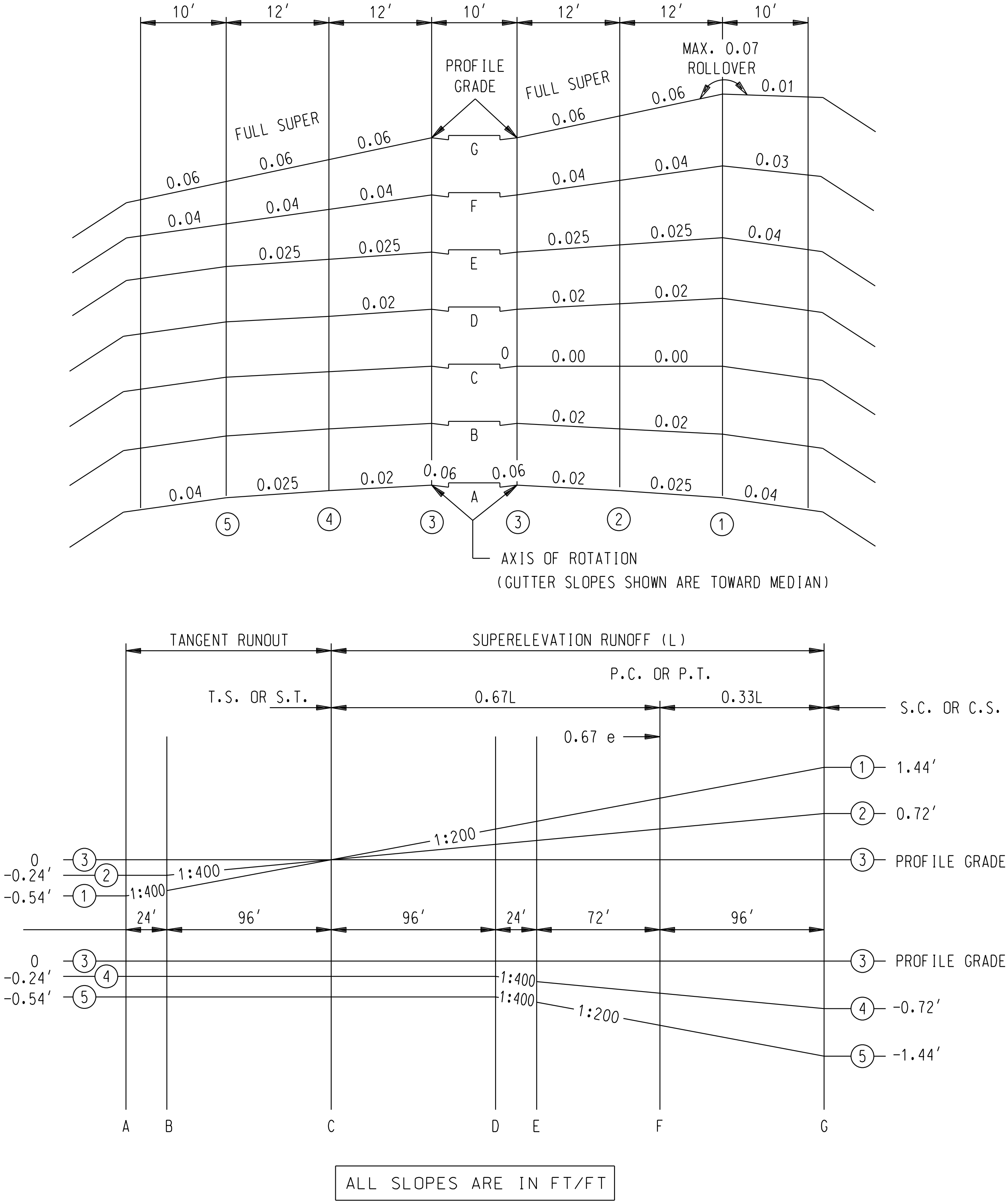
SUPERELEVATION 3-LANE HIGHWAY (LEFT)
Axis Of Rotation At "Hip Point"
Figure 3-3.04C



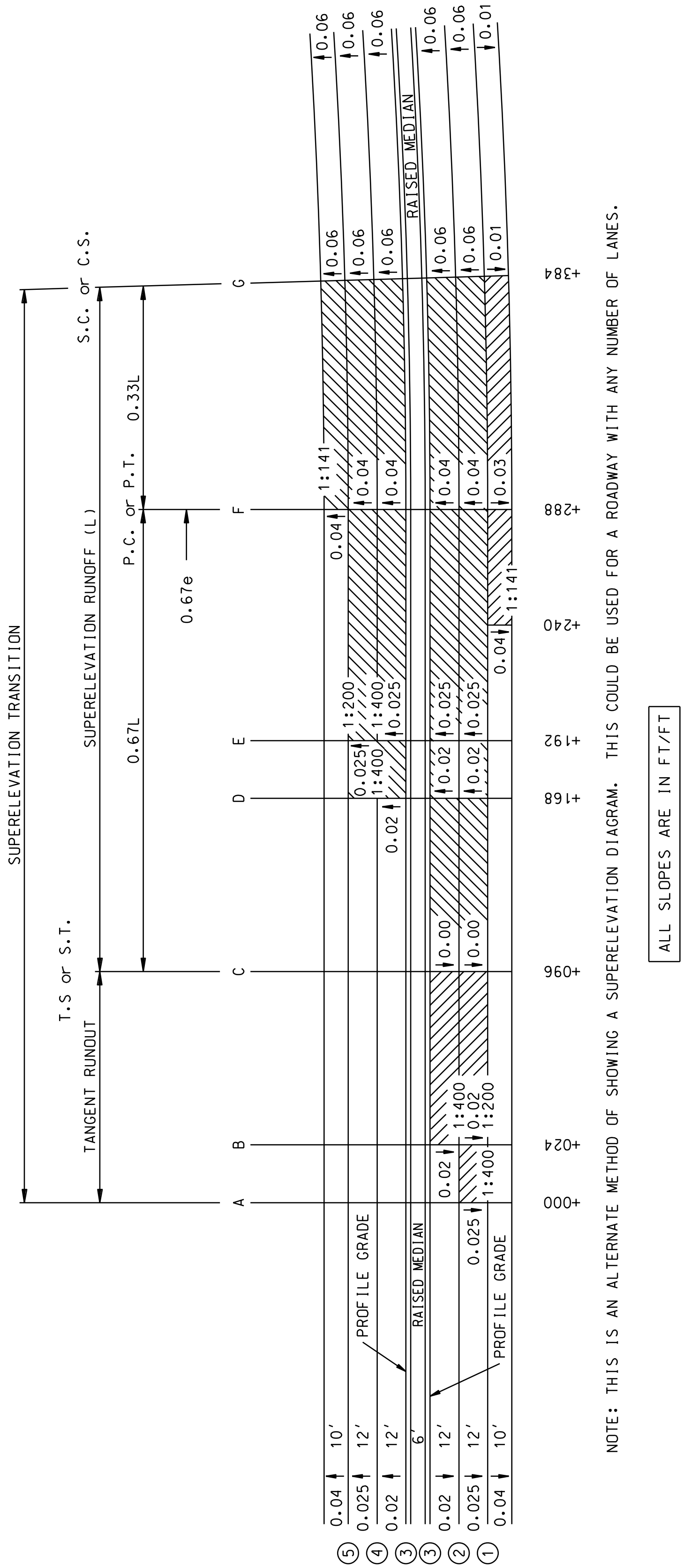
SUPERELEVATION 4-LANE UNDIVIDED HIGHWAY
Axis Of Rotation At "Hip Point"
Figure 3-3.04D



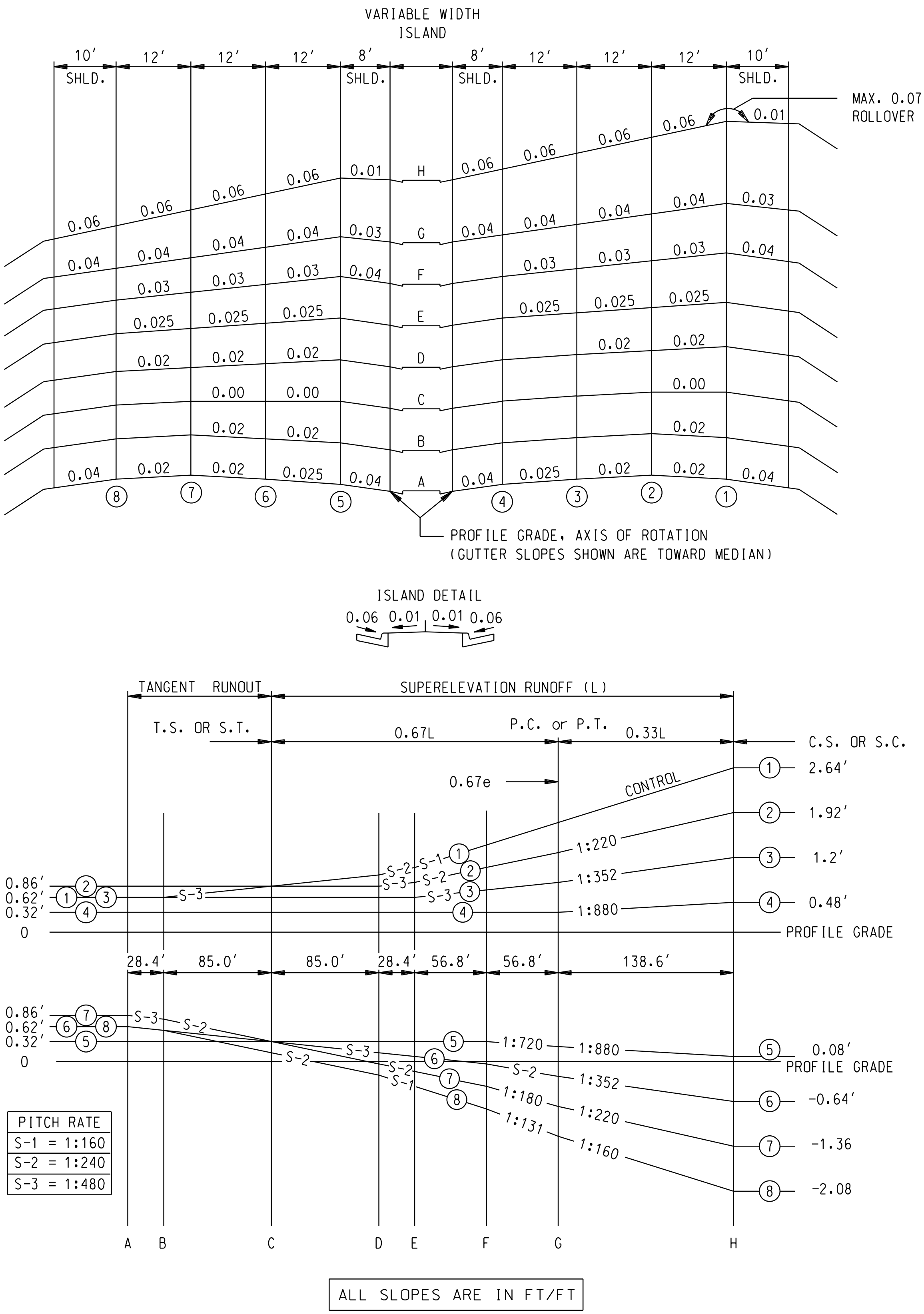
SUPERELEVATION 4-LANE DIVIDED HIGHWAY (NO INSIDE SHOULDER)
Axis Of Rotation At Medium Edge Of Pavement
Preferred Design
Figure 3-3.04E(1)



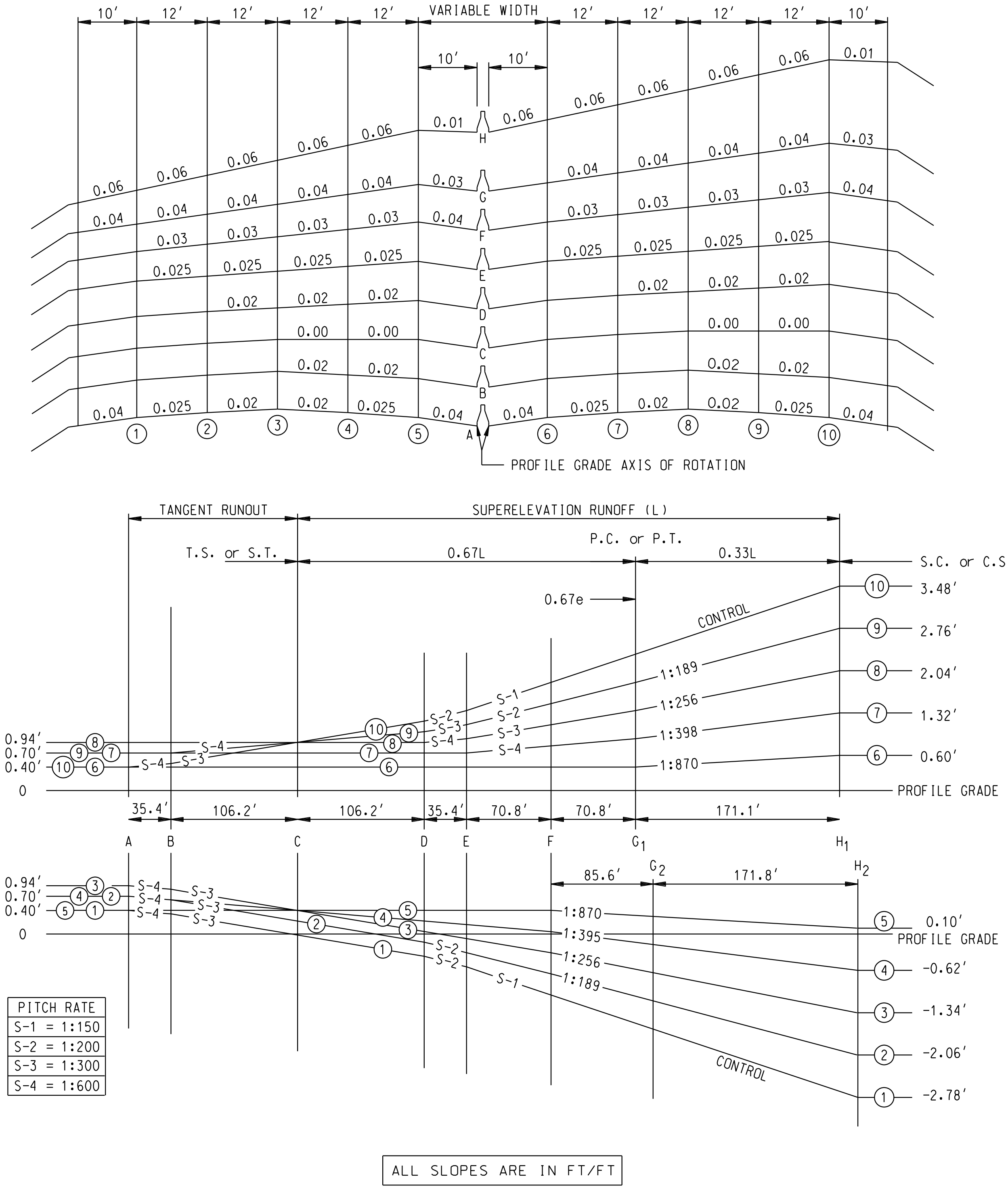
SUPERELEVATION 4-LANE DIVIDED HIGHWAY (NO INSIDE SHOULDER)
Axis of Rotation at Median Edge of Pavement
Alternate Design
Figure 3-3.04E(2)



SUPERELEVATION 4-LANE DIVIDED HIGHWAY (NO INSIDE SHOULDER)
Axis of Rotation at Median Edge of Pavement (Alternate Design)
Figure 3-3.04E(3)



SUPERELEVATION 6-LANE DIVIDED HIGHWAY (INSIDE SHOULDER)
Axis of Rotation at Median Edge of Pavement
Figure 3-3.04F



SUPERELEVATION 8-LANE DIVIDED HIGHWAY (INSIDE SHOULDER)
Axis of Rotation at Inside Edge of Median Barrier
Figure 3-3.04G

3-3.07 Deceleration Lane

Development of superelevation of the deceleration lane is to be accomplished according to Figure 3-3.07A, with the following supplements:

Superelevation runoff should be accomplished in a distance determined by a transition rate of 1:200 maximum.

A grade should be laid on the outer edge of the deceleration lane and ramp that will result in a smooth profile.

3-3.08 Acceleration Lane

Development of superelevation of the acceleration lane is to be accomplished according to Figure 3-3.08A, with the following elaboration:

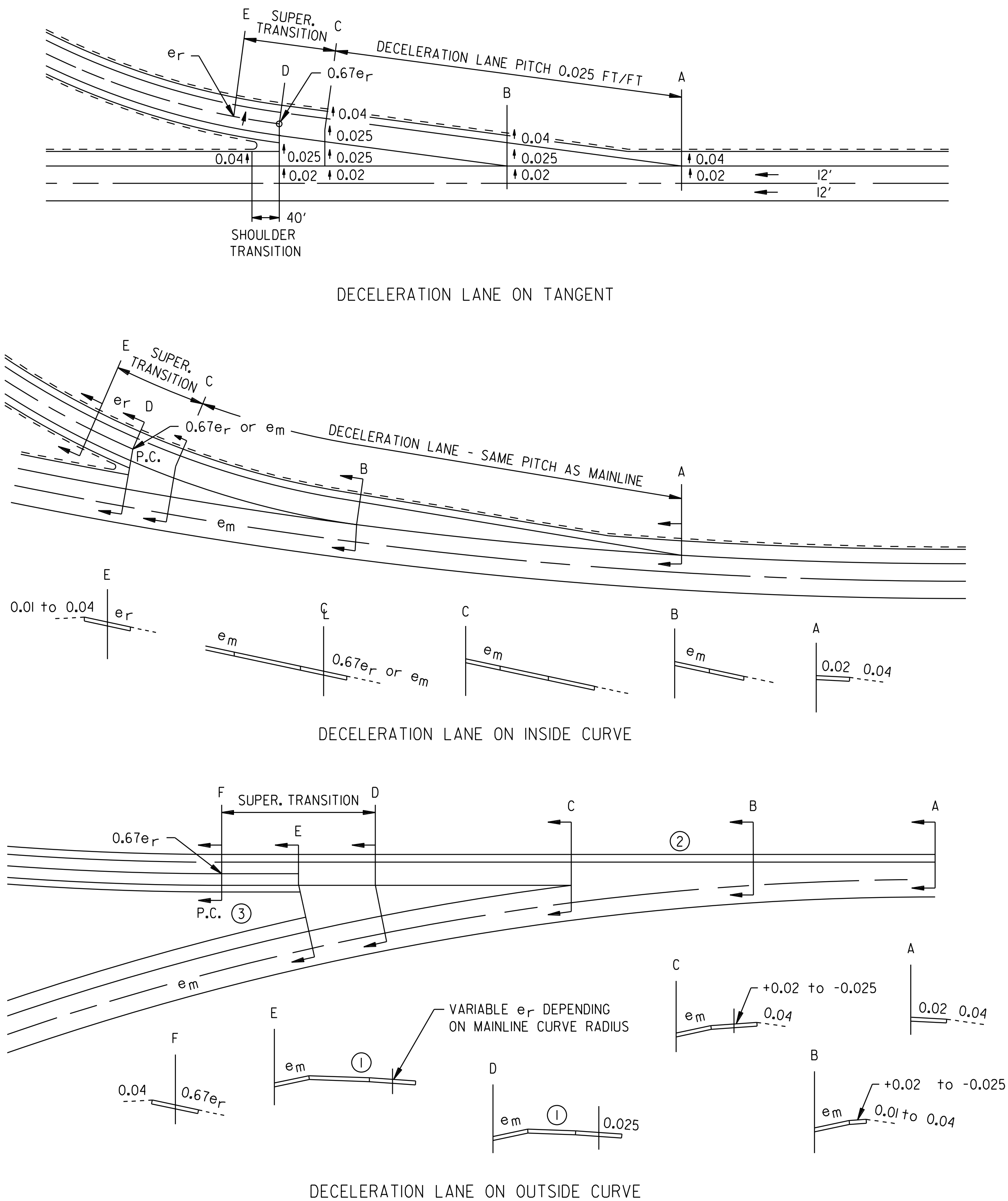
If superelevation is required on the ramp, it is developed so that the ramp superelevation is equal to $0.67e_r$ at the gore nose (Point B).

The superelevation of the acceleration lane should be 0.025 ft/ft at the end of the offset taper (see Figure 6-2.04A for definition). This is a maximum distance of 289 ft and may be less according to the criteria for acceleration lanes as presented in Section 6-2.04.

The transition length from e_r to $0.67e_r$ and from $0.67e_r$ to 0.02 ft/ft. should be determined by a distance at a transition rate not to exceed 1:200.

The axis of rotation is normally about the inside edge of the acceleration lane.

If the main line curves to the right, the superelevation of the acceleration lane is the same as the main line, but not less than 0.025 ft/ft.



e_m = MAINLINE SUPERELEVATION

e_r = RAMP SUPERELEVATION

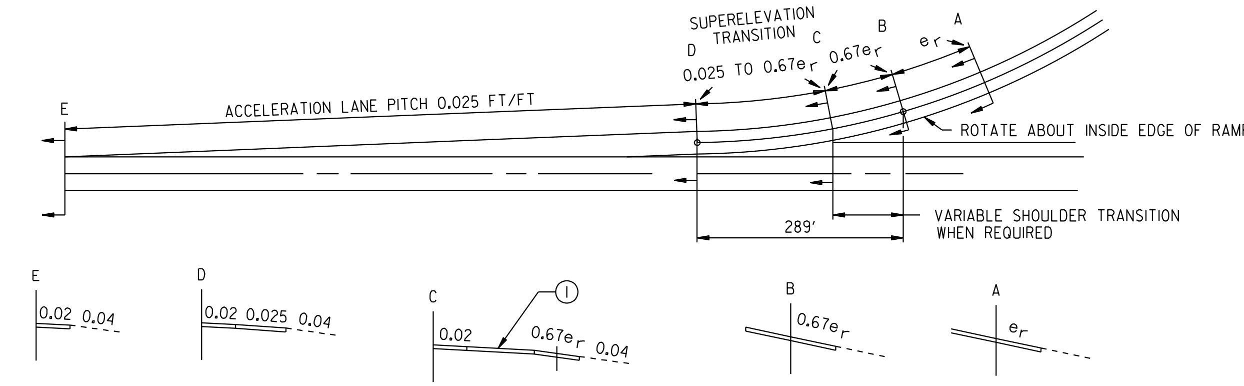
(1) ATTEMPT TO SLOPE GORE AREA AWAY FROM THE MAINLINE LANES AT 0.01 FT/FT MINIMUM.

(2) WHEN MAINLINE CURVE IS 2°00′ OR FLATTER, USE STANDARD DECELERATION TAPER (SEE CHAPTER 6)
WHEN MAINLINE CURVE IS 2°00′ OR SHARPER, SEE FIGURE 6-2.03D.

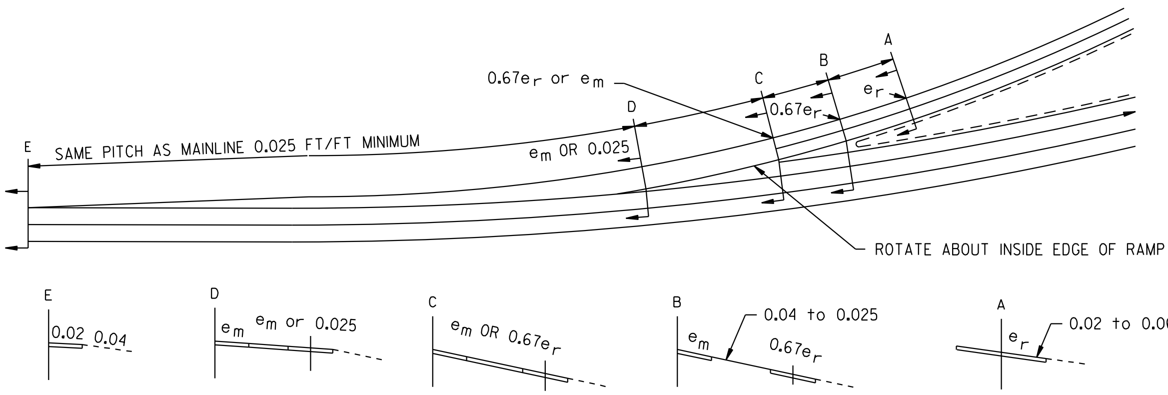
(3) WHEN MAINLINE CURVE IS SHARPER THAN 2°00′, LOCATION OF RAMP P.C. VARIES.

SUPERELEVATION AT DECELERATION LANE

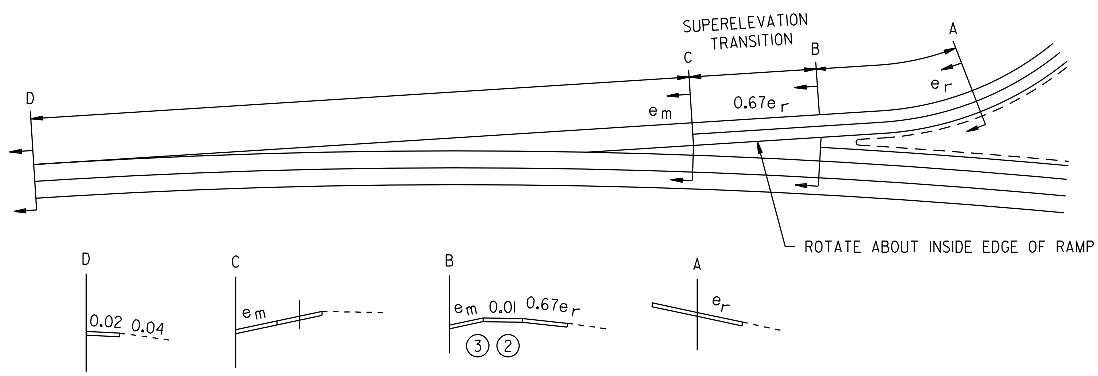
Figure 3-3.07A



ACCELERATION LANE ON TANGENT



ACCELERATION LANE ON INSIDE CURVE



ACCELERATION LANE ON OUTSIDE CURVE

e_m = MAINLINE SUPERELEVATION
e_r = RAMP SUPERELEVATION

① GORE AREA SLOPE VARIABLE 0.025 FT/FT MINIMUM TO 0.04 FT/FT MAXIMUM.
② MINIMUM GORE SLOPE 0.01 FT/FT AWAY FROM MAINLINE
③ MAXIMUM ALGEBRAIC DIFFERENCE IN CROSS SLOPE BETWEEN THRU LANE AND SHOULDER 0.07 FT/FT.

SUPERELEVATION AT ACCELERATION LANE
Figure 3-3.08A

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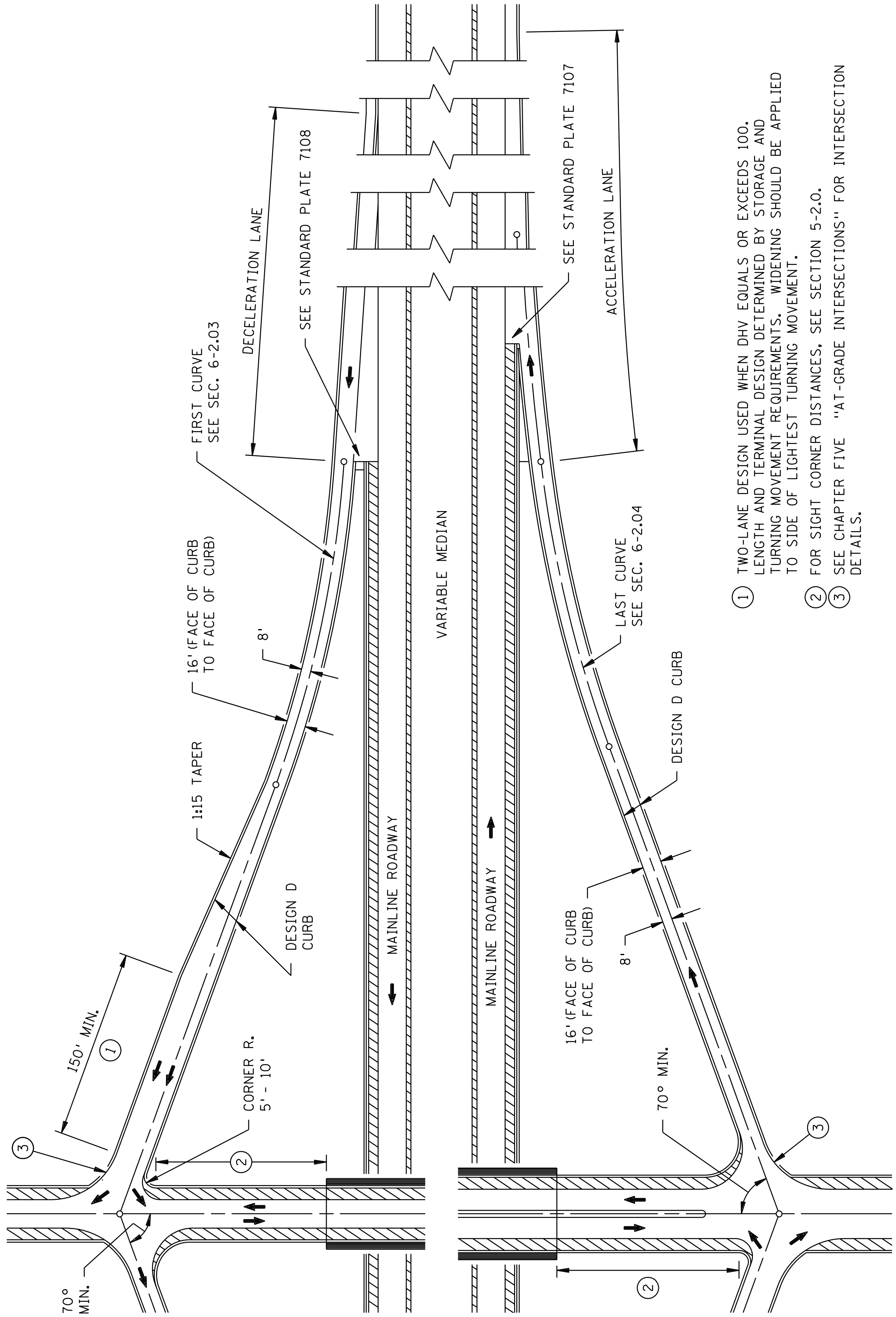

DIAGONAL RAMP DESIGN
DIAMOND INTERCHANGE - URBAN
Figure 6-3.02B

6-3.04 Design Elements

6-3.04.01 Design Speed

The design speed of the ramp proper should conform to the expectations of drivers and fit the constraints and topography of each location. In practice this involves designing the curve adjoining the mainline terminal to a certain percentage of the mainline design speed, depending on context, degree of constraint, and construction cost. The other portions of the ramp are designed based loosely on an assumed speed profile along its length. For ramps that terminate at an intersection, uniform deceleration to a stop condition is usually appropriate. Direct and outer connections are most often designed for a constant speed. For semi-direct connections, the portion between the mainline terminals is usually designed to a somewhat lower speed than the terminal curves, typically dictated by site specifics and interchange configuration.

For a given mainline design speed, Table 6-3.04A gives the corresponding ranges of ramp design speed and associated minimum radius, applicable to the first/last curve adjoining the mainline terminal (but not the transitional curves to/from the main curve).

1. On diagonal ramps (such as ramps in diamond or parclo interchanges), the minimum design speed is the value from the lower range of Table 6-3.04A. In all but the most constrained situations (buttonhook configurations and urban core locations, for example), the desirable minimum design speed is the value from the middle range of the same table. To avoid excessive interchange footprints, design speeds in the high range are not recommended for diagonal ramps having reversing curvature, particularly those in parclos.
2. For loops, AASHTO recommends a design speed no less than 20 mph (110-ft radius) for use with high-speed highways and encourages above-minimum designs in less constrained locations. Radii between 140 ft (22.5 mph) and 170 ft (25 mph) have exhibited good performance with typical freeway design speeds (50 mph to 70 mph) where spiral or robust circular transition treatments are used (see 6-3.04.02). A maximum practical radius is 250 ft (30 mph), above which space requirements and travel times become excessive.
3. On semi-direct connections (as shown in Figure 6-1.03K) as well as outer connections in cloverleaf and semi-directional interchanges, the minimum design speed is the value from the middle range of Table 6-3.04A. This also applies to two-lane semi-direct connections.
4. A direct connection (as shown in Figure 6-1.03L) often carries a mainline route or has comparable significance or traffic demand. In these cases, a uniform design speed along its entire length based on guidelines for mainline highways may be appropriate. A value somewhat lower than for an open-road condition is often justified, however, to fit configuration and constraint. The minimum design speed for any direct connection is the value from the middle range of Table 6-3.04A, not less than 40 mph.

Refer to Chapter 3 for criteria pertaining to superelevation rates and transitions. Generally apply superelevation to the first/last curve per Table 3-3.02A and the selected ramp design speed; however, curves less than 200 feet in length may be sloped at the normal cross slope rate to avoid near-continuous transitioning though the curve. To simplify design, secondary curves on diagonal ramps should be superelevated only as necessary to limit side friction to f_{max}, based on Figure 3-3.03A and an assumed speed at that point on the ramp. Loops should always receive full superelevation (0.06 to 0.08 (ft/ft, m/m)).

Table 6-3.04A
RAMP DESIGN SPEEDS

Highway Design Speed (mph)	40	45	50	55	60	65	70	75
Ramp Design Speed (mph)								
High Range (85%)	35	40	45	50	50	55	60	65
Middle Range (70%)	30	30	35	40	45	45	50	55
Low Range (50%)	20	22.5	25	27.5	30	30	35	40
Corresponding Minimum Radius (ft) Based on 0.08 (ft/ft) Maximum Superelevation								
High Range	350	465	600	760	760	960	1,200	1,500
Middle Range	250	250	350	465	600	600	760	960
Low Range	110	140	170	210	250	250	350	465

6-3.04.02 Horizontal Alignment

Horizontal alignment will be largely determined by the selected design speed. The minimum radii given in Table 6-3.04A are computed based on the values of maximum side friction for rural roadways presented in Table 3-2.03A; the values therein should be extrapolated for design speeds under 30 mph (50 km/h). Ramps and loops are to be designed using these rural side friction values regardless of the cross section design (rural or urban). All ramps should be as directional and flat-curved as possible. This applies, for example, on diagonal ramps at cloverleaf interchanges. The diagonal ramp should be as directional as possible, but may be allowed to follow a reverse curve path around the loop if site conditions are restrictive. Loops pose particular problems. The preferred design is to provide a 3-centered compound curve, the center curve being the minimum radius. The arrangement may be symmetrical or asymmetrical as may be appropriate for any variance in design speed between the two intersecting highways. A 3-centered arrangement allows for a transition between the mainline to the sharpest part of the loop curve, and it eases the acceleration and deceleration problems at either ramp end. For ramps and loops, the ratio of the flatter radius to the sharper one should not exceed 2:1. The length of the flatter transition curve should allow for a desirable acceleration/deceleration rate of 2 mph/sec (3 km/h/sec), and a minimum rate of 3 mph/sec (5 km/h/sec). It is also acceptable to provide a loop of constant-radius curvature. Desirable stopping sight distances should be used to check horizontal curvature. The values and the methodology are presented in Section 3-2.0. The desirable first curve of an exit ramp and the last curve of the entrance ramp are described in Sections 6-2.03 and 6-2.04. See Figure 6-2.03C.

6-3.04.03 Vertical Alignment

Maximum grades for vertical alignment cannot be as definitely expressed as for highway mainline, but preferably should not exceed 5 percent. General values of limiting gradient for ramps are shown in Table 6-3.04B, but for any one ramp the gradient to be used is dependent upon a number of factors peculiar to that site and quadrant alone. These factors include the following:

1. The flatter the gradient on the ramp, the longer it will be.
2. The steepest gradients should be designed for the center part of the ramp. Landing areas or storage platforms at at-grade intersections with ramps should be as flat as possible, as discussed in Section 5-2.02.
3. Short upgrades of 7 to 8 percent permit safe operation without unduly slowing down passenger cars. Short upgrades of up to 5 percent do not unduly affect trucks and buses.
4. Downgrades on ramps should follow the same guidelines as upgrades. They may, however, safely exceed these values by 2 percent, with 8 percent considered the desired maximum.
5. Ramp gradients and length can be significantly impacted by the angle of intersection between the two highways and the direction and amount of gradient on the two mainlines.

Ramp profiles usually have vertical curves at either end, with a straight grade in the center portion. The vertical curves should have designs which meet the criteria for desirable stopping sight distance as presented in Section 3-4.0. If vertical curves are designed at the mainline/ramp junctions, they should meet the design speed of the ramp.

Table 6-3.04B (U.S. Customary)
RAMP GRADIENT GUIDELINES

RAMP DESIGN SPEED (mph)	15	20	25	30	35	40	45	50
MAXIMUM GRADE (%)	8	8	7	7	6	6	5	5

Table 6-3.04B (Metric)
RAMP GRADIENT GUIDELINES

RAMP DESIGN SPEED (km/h)	30	40	50	60	70	80
MAXIMUM GRADE (%)	8	7	7	6	5	5

6-3.04.04 Cross Section

The lane and shoulder width are determined by the ramp's urban or rural character and its horizontal curve radius. Table 6-3.04C provides the necessary information.

Figures 6-3.04A and B illustrate the various ramp and loop cross section elements of pavement width, curbs, cross slope, side slope, and various pavement designs. Ramp and loop superelevation rates and transition should be as determined in Section 3-3.0. Where D4 curb and gutter is designated, the gutter slope should be the same as the adjacent pavement slope. Striping locations should be in accordance with Chapter 7 of the current MnDOT Traffic Engineering Manual and Part 3 of the current Minnesota Manual on Uniform Traffic Control Device (MN MUTCD).

Table 6-3.04C (Metric)
RAMP PAVEMENT WIDTH[1]

		Width (m)	
RURAL[2]	**Ramp**	7.8	
	Loop	8.4	
URBAN[3]	**Ramp or Loop**	**Radius (m)**	**Width (m)**
		>150	4.8
		90-150	5.4
		70-<90	6.0
		58-<70	6.3
		48-<58[4]	6.6
		38-<48[4]	7.2

1) If ramp metering is anticipated, refer to Section 6-2.08 for design details.
2) Includes 1.8 m right shoulder and 1.2 m left shoulder.
3) Face-of-Curb to Face-of-Curb Width.
4) Radii indicated do not satisfy the minimum criterion presented in Section 6-3.04.01 and should be used only where constraints dictate.

Table 6-3.04C (English)
RAMP PAVEMENT WIDTH[1]

		Width (ft)	
RURAL[2]	**Ramp**	26	
	Loop	28	
URBAN[3]	**Ramp or Loop**	**Radius (ft)**	**Width (ft)**
		>500	16
		300-500	18
		230-<300	20
		190-<230	21
		160-<190[4]	22
		125-<160[4]	24

1) If ramp metering is anticipated, refer to Section 6-2.08 for design details.
2) Includes 6 ft right shoulder and 4 ft left shoulder.
3) Face-of-Curb to Face-of-Curb Width.
4) Radii indicated do not satisfy the minimum criterion presented in Section 6-3.04.01 and should be used only where constraints dictate.