HIGHWAY POLICIES AND PROCEDURES MANUAL

Maryland Department of Transportation
STATE HIGHWAY ADMINISTRATION
Office of Highway Development
Highway Design Division

Director, Highway Development

Chapter	DESIGN	**Ref. No.**: D-89-07AL(H)
Section	ALIGNMENT (HORIZONTAL)	**Effective:**
Subject	GUIDELINES FOR USE OF SUPERELEVATION	**Sheet:** 1 **of** 4

Application: ☒ DESIGN
☒ CONSULTANT ENGINEERING
HYDRAULICS
☒ ENGINEERING SUPPORT
ADMINISTRATION
OTHER

Directive: The following design procedures shall be used for selecting the horizontal alignment and applying superelevation rates.

1. In selecting the radius of curvature for the original alignment of a new OPEN SECTION facility, the minimum radius of curvature should be based upon the criteria contained in the ^{e}max chart of 0.06 found in the 2001 AASHTO "*POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS*," page 159.

2. When applying the superelevation to an alignment, the ^{e}max of 0.08 is to be used for the design of expressway mainlines while all other open section facilities will utilize the ^{e}max of 0.06 (refer to 2001 AASHTO pages 161 and 159, respectively).

3. New CLOSED SECTION urban facilities should be based upon the ^{e}max chart of 0.04 found on page 157 of 2001 AASHTO.

4. On interchange loop design (both entrance and exit loops) the preferred alignment is established utilizing the ^{e}max of 0.08 criteria. As these loops are generally designed for low speed (30 mph), when Right-of-Way or other cost constraints exist, these inner loops may use the ^{e}max of 0.10 criteria in establishing the control radius (refer to page 163, 2001 AASHTO). The use of 0.10 superelevation for the extreme Western Maryland counties (District 6) is discouraged. Due to climatic conditions, the maximum superelevation used in those areas should be 8.0%.

5. On interchange outer ramp design, including directional movements, generally designed for 50 mph or greater, the mainline ^{e}max rate should be utilized with a maximum allowable rate of 8.0%.

6. For at-grade intersection design utilizing channelized free flow right turn ramp movements, the criteria established in Exhibit 3-43 should be utilized (refer to page 201, 2001 AASHTO). At signalized intersections, minimum AASHTO rates should be utilized on the mainline to minimize or avoid adverse slopes (bumps) through the intersection, due to superelevation on the intersecting roadway.

7. Superelevation Transition Lengths

To transition from a normal section to a superelevated section, use the following formula:

$$\text{T.L.} = \frac{\text{Total Change in Pavement Cross Slope}}{\text{"C"}}$$

Where

T.L. = transition length to get from the last normal section to the first fully superelevated section.

"C" = rate of change in pavement cross slope, per foot of longitudinal length, in the transition area.

"C" Factor criteria is established as follows:

"C" Factor	Improvement Type
.0001	Expressways and Urban Highways
.00015	Other Highways
.0002	Directional Ramps and other two-lane ramps
.0003	Single-lane outer ramp
.0004	Inner loops

8. Location of superelevation transition with respect to the horizontal curve.

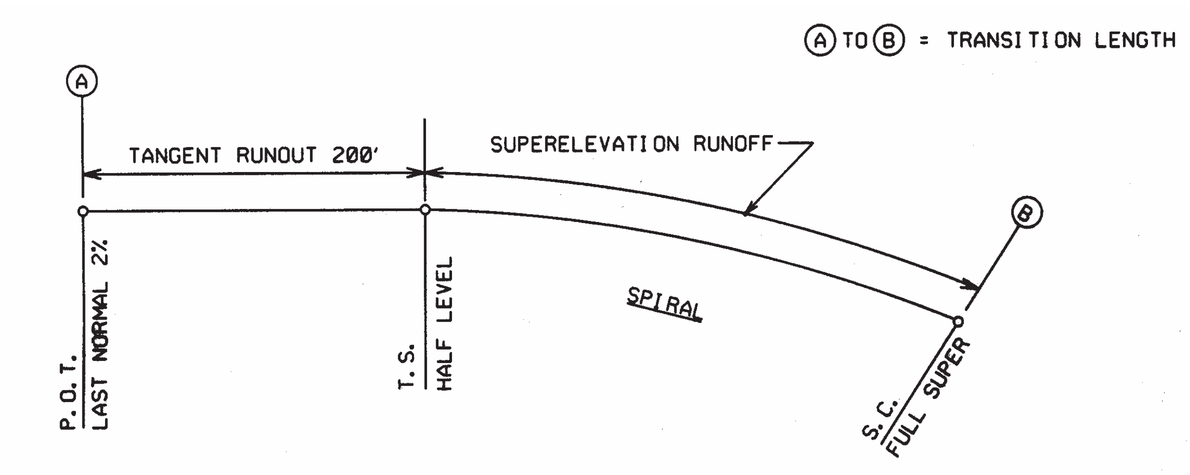
The Administration uses the following distribution of the superelevation transition to the alignment:

a. **Simple Curve.** Generally used on all but selected expressways 1/3 of the transition length into the curve (ahead of PC) and 2/3 of the transition length on the tangent (behind the PC). This application also applies coming out of a curve with respect to the PT.

b. **Spirals.** Where spirals are utilized on selected expressway facilities, the spiral should equal the length of the superelevation runoff. This is the length from the "half level" section to the "full superelevated" section. The TS would be the "half level" section while the SC would be the first "full super" section and the reverse coming out of the spiral. The tangent runout is the length required to accomplish the change in cross slope from normal section to "half level" section. The summation of these two lengths is the "transition length." As spirals are generally only used in the design of expressways, and with the application of the .0001 "C" factor to the formula

$$\text{T.L.} = \frac{\text{x-slope change}}{\text{"C"}},$$

The following applies:



Length of Spiral = Super Rate divided by "C" Factor

when S = 0.08 use a 800 ft spiral
when S = 0.06 use a 600 ft spiral
etc.

9. Minimum Tangent Length Between Reversing Curves on Mainline Alignment.

   When establishing the original alignment of a new facility, the use of reverse curves shall be avoided. Reversing curves shall be sufficiently separated to provide distance to obtain appropriate superelevation runoff of each curve.

   In general, the minimum tangent between reversing curves should be the summation of the 2/3 distance computed for each curve. A minimum distance of 500 ft is generally preferred on alignments other than expressways.

10. Minimum Tangent Length Between Reversing Curves on Ramp Alignments.

    When establishing the original alignment of outer ramps, the use of reversing curves is discouraged. Reversing curves shall be sufficiently separated to provide distance to obtain appropriate superelevation runoff of each curve.

    Where interchange design is constrained by environmental concerns, abutting development (excessive right-of-way costs and/or construction costs), the use of wrap-around outer ramp alignments are sometimes required. In these special cases, attention to the alignment is necessary. The superelevation considered shall be obtained from the ^{e}max chart of 0.06, to minimize the required transition length.

    If reversing curves must be used, the reversing superelevation is accomplished by setting the level section (0.0%) at the P.R.C. and transition to and from this section using appropriate "C" factor.

11. Avoid the use of "broken-back" curves. The use of compound curves is preferred over short tangents between curves in the same direction.

Application:
- ☒ DESIGN
- ☒ CONSULTANT ENGINEERING
- HYDRAULICS
- ☒ ENGINEERING SUPPORT
- ADMINISTRATION
- OTHER

Directive: The following guidelines establish the design procedures for selecting vertical alignment.

Alignment. Of all the various elements to consider when designing a new highway, the selections of the horizontal and vertical alignments are of greatest importance in establishing the character of the highway. Alignment affects the operating speeds, sight distance capacity, and has a significant impact on safety operations of the highway. Once the line and grade are established, rarely can we afford to return and make significant improvements.

Vertical Alignment. Vertical alignment, defined as a mix of tangent gradients and vertical (parabolic) curves, is also referred to as the profile grade line (PGL)

General Controls. The characteristics of vertical alignment are greatly influenced by type of terrain, design speed and roadway classification. Additional factors impacting the vertical alignment of a highway are locations of utilities, location of existing major intersecting roadways, bridge structures, earthwork balance and coordination with horizontal alignment, etc. Within these controls, several general factors must be considered.

1. A smooth gradeline with gradual changes, consistent with the type of highway and the character of the terrain.

2. Avoid numerous breaks and short length grades.

3. Avoid placing a low point of a sag vertical curve in cut sections. To drain these low points, additional construction cost may be incurred.

4. Short humps in vertical alignment, that tend to drop out of sight, shall be avoided whether on a horizontal curve or a tangent alignment.

5. Maintain moderate grades through intersections to facilitate turning movements.

6. Consider auxiliary lanes where passing opportunities are limited and it is possible that the capacity may be jeopardized by slow moving trucks or other vehicles either ascending or descending.

7. On four-legged, at-grade intersecting roadways, the profile "through the intersection" (both left and right of the mainline) shall be reviewed as one continuous vertical alignment.

Maximum Grades. Maximum grades are based upon the functional classification of the highway, terrain over which the highway traverses and the Design Speed. (Refer to Table VA-1). The maximum grades shown shall be used only where absolutely necessary rather than as a value to be used in most cases. Grades much flatter than maximum normally shall be used.

Minimum Grades. Minimum grades are generally a function of adequate drainage. On roadways, a minimum grade of 0.5 percent is desired. Use of flatter grades may be justified under extenuating circumstances only.

Minimum Ditch Grades. Roadside and median ditches may require grades steeper than the profile grade of the roadway to adequately handle drainage. Special attention shall be directed to minimum ditch grades. Any ponding of water in roadway ditches, particularly on soils which become unstable when wet, can have a detrimental effect on the subgrade. Ditch gradients shall not be less than 0.5 percent and preferably steeper. Refer to Chapter 3, "Open Drainage," of the Highway Drainage Manual for additional control for ditches (I-3-A-1).

Critical Length of Grade. The steepness of the grade is not the only control when considering vehicle operating characteristics. The length of the grade may become a critical factor and shall be considered.

When passing opportunities are limited, long lines of vehicles queue behind the slower vehicle, reducing both average operating speed and highway capacity.

The term "Critical Length of Grade" is indicated as the maximum length of a specific grade upon which a loaded truck, with a weight to horsepower ratio of 300, can operate without a reduction in speed of 10 mph. The data contained in 2001 AASHTO Exhibit 3-63 shows the speed reduction resulting from various combinations of grade and length of grade.

On highways with moderate to heavy traffic volumes, where critical lengths of grade are exceeded, consideration shall be given to providing a climbing lane. By itself, this analysis is not a warrant for climbing lanes, but an indication that further study may be required. Some factors such as percentage of passing sight distance, percentage of heavy trucks, desired level of services, service volume, cost, etc., are taken into consideration and capacity analysis performed.

Summary. Climbing lanes offer an inexpensive means of overcoming capacity losses and improve operation where congestion on grades is caused by slow trucks in combination with high traffic volumes. The addition of climbing lanes on some existing highways could defer reconstruction for many years. On new designs, climbing lanes could make a two-lane facility adequate, whereas a more costly multilane might be necessary without them. Climbing lanes are warranted where the critical length of grade is exceeded and the level of service obtainable is one level poorer than that desired for the facility.

Climbing Lane Criteria. Climbing lanes shall be as wide as the through lanes, preferably 12 feet. The cross slope shall be the extension of the main line cross slope for alignments on tangent and for the low side of superelevated roadways. The maximum superelevation of climbing lanes on the high side of superelevated curves shall be limited to 4.0%. A usable shoulder width of 4 feet is acceptable adjacent to climbing lanes.

A tapered section, desirably 25:1, but at least 150 feet long shall precede the beginning of the climbing lane. Ideally, the climbing lane shall extend beyond the crest of the vertical curves to a point where the truck could attain a speed that is the mainline speed. In some instances, this may not be practical; therefore, a practical point to end the climbing lane is where the truck can return to the normal lane without undue hazard, that is, where sight distance becomes adequate to permit passing with safety. In addition, a desirable taper based on a ratio of 50:1 shall be added, or a minimum taper length of 200 feet.

Emergency Escape Ramps. Emergency Escape Ramps shall be considered in Allegany, Garrett, Frederick and Washington counties on new expressways and arterial highways that utilize a sustained grade of 4.0% or steeper and a length of 1/2 mile or more. (Refer to 2001 AASHTO, page 263, for various types of ramps).

Vertical Curve Design. Vertical curves shall result in a design that is safe, comfortable, adequate for drainage and smooth in appearance.

The major control for safe operation on vertical curves is adequate stopping sight distance. In all normal instances on crest vertical design, the designer shall use the criteria based on the height of eye of 3.5 feet and a height of object of 6 inches. The crest of the curve shall not obstruct the line of sight. In areas of complex and multiple decision points, additional sight distance shall be provided (Refer to 2001 AASHTO, Elements of Design, pages 115-117).

Nighttime driving conditions govern sag vertical curves. For safety, a sag vertical curve shall be long enough that the illuminated distance (headlight beam) is nearly the same as the stopping sight distances.

For main line vertical alignments the following vertical curve lengths shall be considered minimum

CREST	1000 feet (MINIMUM)
SAG	800 feet (MINIMUM)

For flat gradients where sight distance is not a factor and the algebraic difference in grades (A) is small, the minimum length of curve for mainline roadways shall be no less than the design speed in meters. Computed vertical curves may not be necessary and are considered the designer's option when the algebraic difference in grades (A) is 0.3% or less for highways using design speed of 50 mph or greater and 0.5% or less for highways using a design speed less than 50 mph.

The length of vertical curve divided by the algebraic difference (L/A) represents the horizontal distance required to effect a 1 percent change in gradient along the curve. This quotient is termed K and is useful for determining minimum lengths of curves as well as high and low points on vertical curves. The horizontal distance from the point of vertical curve (PVC) to the high point of crest and the low point of sag vertical equals K times the approach gradient.

Drainage affects the design of vertical curves. On the pavement surface of curbed sections, no difficulty with drainage is experienced if the curve is sharp enough so that a minimum grade of 0.3% is reached at a point about 50 feet from the crest (or sump). Special attention to drainage shall be exercised where a K-value in excess of 167 is used.

Elevation of the Profile Grade. In the case of Special Project type of improvements and most urban areas, there is little opportunity for large variation in the profile gradeline elevation. The existing facility and/or adjacent roadside development usually control these elevations.

However, for new construction or major reconstruction in rural areas, particular attention shall be given to the elevation of the proposed grades. This is particularly true in relatively low areas with level terrain. Structural problems can occur where the pavement bases or upper portions of the embankment become saturated with water or high water encroaches on the roadway shoulders and surface.

Generally, the finished grade elevation shall be above the surrounding terrain in these cases and preferably higher in the case of a relatively high normal water table. Where there is evidence of occasional standing water in adjacent ditches or fields, the gradeline shall be high enough to assure drainage of the pavement base course at high water level. This can be of particular concern in lower Eastern Shore counties. Generally, when setting the vertical alignment in these counties, embankment areas shall not be less than 3 feet in depth. This will eliminate the need to grub the embankment areas in accordance with Section 101.00 of the Specifications. Allowing the root mat to remain in place will assist in maintaining the stability of the existing ground.

Entrance Profiles. Special attention shall be given to driveways and entrances, particularly on urban construction. Driveway/Entrances are in effect at-grade intersections. Sight distance is a significant design control (generally associated with rural highways) and driveways should be avoided where sight distance is not sufficient. The number of accidents is disproportionately higher at driveway terminals than at other intersections; therefore, their design and location merit considerations. Vertical breaks shall be kept as flat as possible to provide clearance for the under carriage or bumpers of vehicles entering/exiting these points of access. The designer shall be familiar with the Administration's publication "Rules and Regulations for Commercial, Subdivision, Industrial, Residential - Entrances to State Highways." In addition, additional data for grade tie-ins for urban highways is illustrated on Standard No.'s MD 630.01, 630.02 and 630.11 and Figure VA-2 of these procedures.

TABLE VA- 1 MAXIMUM MAINLINE GRADES FOR MARYLAND HIGHWAYS

TYPE OF TERRAIN	DESIGN SPEED IN MPH			
	40	**50**	**60**	**70**
LEVEL	5%	4%	3%	3%
ROLLING	6%	5%	4%	4%
MOUNTAINOUS	8%	6%	6%	5%

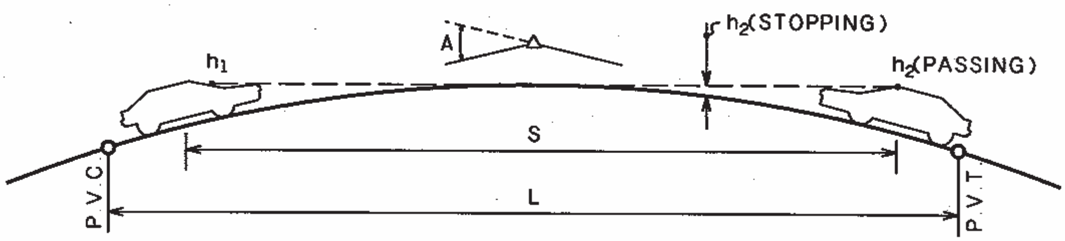
1. Vertical alignment should be designed in conjunction with the horizontal alignment.
2. Maximum grades should be used as infrequently as possible. Use of flatter grades is encouraged. In URBAN areas where development precludes the use of flatter grades, for short grades less than 500 ft and for one-way downgrades (except in mountainous terrain) the maximum gradient may be 1.0% steeper.
3. The type of terrain pertains to the general character of the specific route corridor. Routes in valleys of mountainous areas that have all the characteristics of roads traversing level or rolling terrain should be classified as rolling or level as the case may be.
4. For local roads and streets, refer to applicable County standards.

TABLE VA-2 SIGHT DISTANCE CRITERIA

DESIGN SPEED IN MPH	30	40	50	60	70
STOPPING SIGHT DISTANCE (feet)	200	325	475	650	850
CREST K VALUE	40	100	215	400	680
SAG K VALUE	40	70	110	160	220
PASSING SIGHT DISTANCE (feet)	1100	1500	1800	2100	2500
CREST K VALUE	440	610	1070	1600	2250
DECISION SIGHT DISTANCE (feet)	625	825	1025	1300	1625

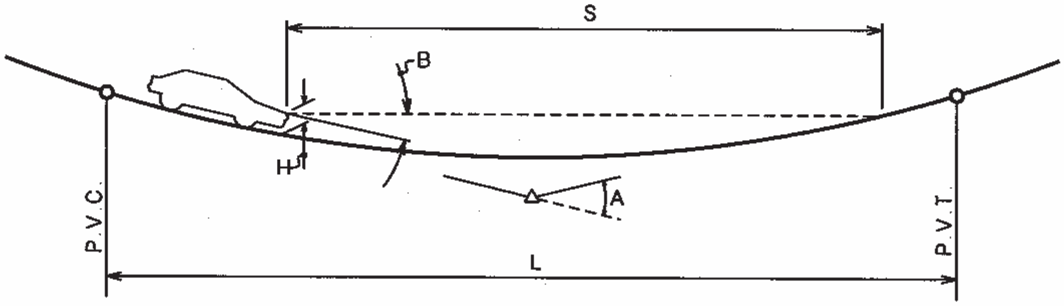
In using this table, the designer can check his plan to compare all curves using the design K value (L=KA).

NOTE: Refer to HORIZONTAL ALIGNMENT - DESIGN CONTROLS, page 4 of 5, for additional information.



CREST

FORMULA : WHEN $S<L$; $L = AS^2 \div 100 \left(\sqrt{2h_1} + \sqrt{2h_2}\right)^2$



SAG

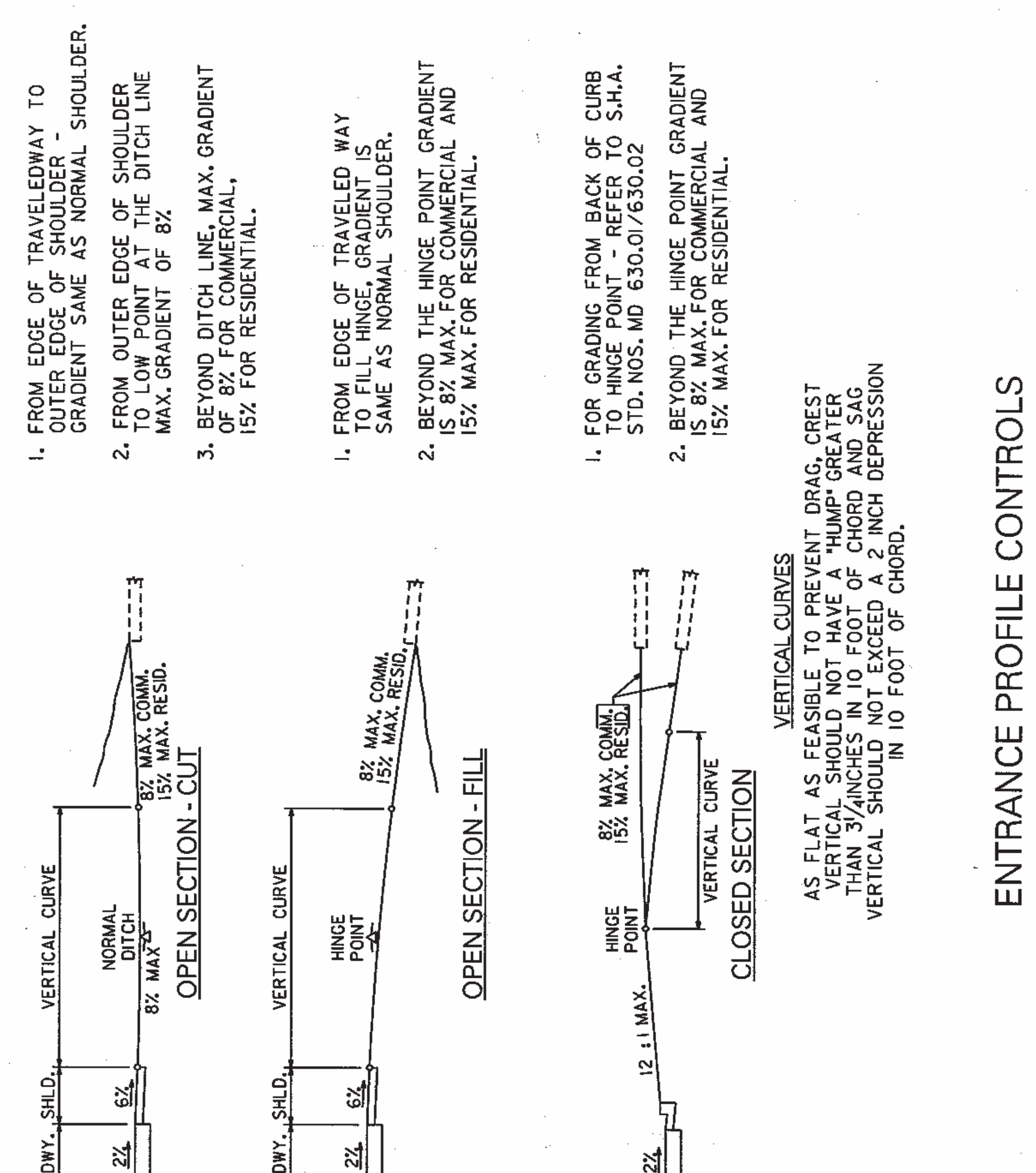
FORMULA : WHEN $S<L$; $L = AS^2 \div (400 + 3.5\ S)$

L = LENGTH OF VERTICAL CURVE (FEET)
A = ALGEBRAIC DIFFERENCE IN GRADES (%)
S = SIGHT DISTANCE (FEET)
K = VERTICAL CURVE (L/A)
H = HEADLIGHT HEIGHT (2 FEET)
B = UPWARD DIVERGENCE OF LIGHT BEAM (1 DEGREE)

	PREFERRED	ACCEPTABLE
h_1	3.0'	3.5'
h_2 (STOPPING)	0.33'	0.5'
h_2 (PASSING)	4.0'	4.25'

VERTICAL CURVE - SIGHT DISTANCE SKETCH

FIGURE VA-1



1. FROM EDGE OF TRAVELEDWAY TO OUTER EDGE OF SHOULDER - GRADIENT SAME AS NORMAL SHOULDER.
2. FROM OUTER EDGE OF SHOULDER TO LOW POINT AT THE DITCH LINE MAX. GRADIENT OF 8%
3. BEYOND DITCH LINE, MAX. GRADIENT OF 8% FOR COMMERCIAL, 15% FOR RESIDENTIAL.
RDWY. SHLD. VERTICAL CURVE
2% 6% NORMAL DITCH 8% MAX. 8% MAX. COMM. 15% MAX. RESID.
OPEN SECTION - CUT
1. FROM EDGE OF TRAVELED WAY TO FILL HINGE, GRADIENT IS SAME AS NORMAL SHOULDER.
2. BEYOND THE HINGE POINT GRADIENT IS 8% MAX. FOR COMMERCIAL AND 15% MAX. FOR RESIDENTIAL.
RDWY. SHLD. VERTICAL CURVE
2% 6% HINGE POINT 8% MAX. COMM. 15% MAX. RESID.
OPEN SECTION - FILL
1. FOR GRADING FROM BACK OF CURB TO HINGE POINT - REFER TO S.H.A. STD. NOS. MD 630.01/630.02
2. BEYOND THE HINGE POINT GRADIENT IS 8% MAX. FOR COMMERCIAL AND 15% MAX. FOR RESIDENTIAL.
2% 12 : 1 MAX. HINGE POINT 8% MAX. COMM. 15% MAX. RESID. VERTICAL CURVE
CLOSED SECTION
VERTICAL CURVES
AS FLAT AS FEASIBLE TO PREVENT DRAG, CREST VERTICAL SHOULD NOT HAVE A "HUMP" GREATER THAN 3 1/4 INCHES IN 10 FOOT OF CHORD AND SAG VERTICAL SHOULD NOT EXCEED A 2 INCH DEPRESSION IN 10 FOOT OF CHORD.
ENTRANCE PROFILE CONTROLS

FIGURE VA-2

HIGHWAY POLICIES AND PROCEDURES MANUAL

	Maryland Department of Transportation **STATE HIGHWAY ADMINISTRATION** **Office of Highway Development** **Highway Design Division**	Director, Highway Development
Chapter	DESIGN	**Ref. No.**: D-90-07AL(H)
Section	ALIGNMENT (HORIZONTAL)	**Effective:**
Subject	DESIGN CONTROLS	**Sheet:** 1 **of** 5

Application: ☒ DESIGN
☒ CONSULTANT ENGINEERING
HYDRAULICS
☒ ENGINEERING SUPPORT
ADMINISTRATION
OTHER

Directive: The following guidelines establish the design procedures for selecting the horizontal alignment.

Alignment. Of all the various elements to consider when designing a new highway, the selections of the horizontal and vertical alignments are of greatest importance in establishing the character of the highway. Alignment affects the operating speeds, sight distance, capacity, and has a significant impact on safety operations of the highway. Once the line and grade are established, rarely can we afford to return and make significant improvements.

Coordination of Horizontal and Vertical Alignments. Horizontal alignment shall be designed in harmony with the vertical alignment. To analyze both alignments, a good practice is to superimpose the two alignments on the same mapping.

1. Horizontal and vertical tangents and curves shall be similar, with respect to position, length, and design speed.

2. Horizontal curves shall be slightly longer than the vertical curves.

3. Sharp horizontal curves shall not be introduced either at or near the crest of a pronounced vertical curve or at or near the bottom of a sag vertical curve. Both alignments shall be as flat as feasible on the approach to and at intersections, where sight distance along both roadways is important and vehicles may have to slow, turn or stop (Refer to 2001 ASHTO pages 283-285 for further data).

4. Short humps in the vertical alignment that tend to drop out of sight shall be avoided, whether on a horizontal curve or on tangent alignment.

5. Intersecting roadway connections shall not be tied in at the top of sharp crest vertical curves.

Horizontal Alignment. The horizontal alignment of a highway is defined as a series of straight-line tangents connected by horizontal curves. Factors that affect the mix of tangents and curves include terrain, right of way consideration, environmental impact, safety and economics.

General Controls. The principal factor controlling the horizontal alignment is the design speed. It is directly related to functional classification, intensity of development and terrain features.

Design speed establishes various basic criteria for certain design elements. Some of these elements are:

1. Maximum degree of curvature and superelevation.
2. Sight distance.
3. Roadway width.
4. Maximum gradients.

The elements of maximum degree of curve and sight distance are directly related to traffic safety and shall not be compromised.

The following general controls shall be considered in arriving at the final horizontal alignment.

Consistency.

1. Consistent design speeds in alignment selection shall always be sought.

2. Alignment shall be as directional as possible but consistent with the topography while considering improved properties and community values.

3. Winding alignment composed of short curves shall be avoided, as it is a cause of erratic operation.

4. Sharp curves shall not be introduced at the ends of long tangents or at the ends of long flat curves. Where sharp curvature is required, it shall be introduced by a series of progressively sharper curves.

5. Use of compound curves for mainline alignment shall be reserved for special restrictive conditions. Their use shall be avoided where curves are sharp.

   Compound curves with large differences in radii produce similar problems that exist with a tangent approach to a circular curve. Where compound curves are necessary, the radius of the flatter curve shall not be more than 50% greater than the radius of the sharper curve.

6. Reverse curves and broken-back curves on mainlines are discouraged.

   The use of transitional spirals shall be considered or adequate tangent length provided between the two curves so that proper superelevation could be obtained.

   Refer to Figure SE-3 "Minimum Length of Tangent Between Reversing Curves" in this chapter under subject "Guidelines For Use of Superelevation" for additional information.

7. When connecting intersecting roadways to the mainline alignment, particularly on crest vertical curves, careful consideration shall be given to assure adequate sight distance is provided.

Length of Curve. A horizontal curve is not required for central angles of 10 minutes or less. For small deflection angles, the horizontal curve length shall be long enough to avoid the appearance of a "kink." For central angles between 1 degree through 5 degrees, the minimum length of curve shall be 1000 feet. For angles less than 1 degree, the minimum length of curve may be 800 feet.

The minimum length of curve for 30 and 40 mph design on mainline highways shall be 15 times the design speed.

The minimum length of curve for design speeds of 50 mph and greater is 1000 feet.

Spirals. On mainline of expressways, the use of spiral curves is encouraged. The length of spiral is equal to the desired superelevation rate times the "C" factor (.0001 for expressways). Half level shall occur at the tangent to spiral point (TS) and again at the spiral to tangent point (ST). Full superelevation shall occur at the spiral to curve point (SC) and curve to spiral point (CS). Refer to Figure HA-1 on sheet 5 of 5 for additional information.

Superelevation. Refer to this chapter, section "Horizontal Alignments," subject "Guidelines for Use of Superelevation."

Bridges. It is advantageous for bridges to be located on tangent sections of the alignment. Often it becomes necessary to locate a bridge on a horizontal curve. In these instances, care shall be used to avoid beginning or ending a curve on a bridge.

Control Lines. Relationships between survey line, base line of construction and the profile grade line shall be clearly identified on the typical section sheets of the plans. The following general criteria should apply.

1. On two-lane roadways and undivided multilane roadways the centerline of survey, centerline of construction, profile grade line and the point where the profile grade elevation is applied shall be located at the center of the typical section.

2. On four lane divided highways with medians, 78 feet and less, the horizontal control shall be at the centerline of the median with a single profile grade. The profile grade elevation shall be applied at the median edge of pavement.

3. On multilane divided highways with relatively wide medians, independent horizontal and/or vertical controls can be established.

Sight Distance. In the design of a highway, there are four basic sight distances to be considered:

1. Stopping - Sight Distance for both crest and sag curves.
2. Passing Sight Distance.
3. Intersection Sight Distance.
4. Decision Sight Distance.

On tangents, the obstruction that limits the driver's sight distance is the road surface at some point on a crest vertical curve. On horizontal curves, the obstruction may be the road surface at a point on a crest vertical curve; or it may be some physical feature outside the traveled way such as longitudinal barrier, cut slope, trees, or foliage, etc. The designer shall check both vertical and horizontal planes for sight distance obstructions.

The designer shall review sight distance across the inside of curves to verify adequate sight distance. Parapet walls, cut slopes including vegetation, etc. may limit sight distance on curves. Where these obstructions can not be removed, adjustment to the normal cross-section or change in alignment may be required to assure adequate sight distance. Refer to page 228, 2001 AASHTO.

Intersection sight distance is the distance required for a driver on a roadway, in a stopped position, to safely depart and cross or enter into the traffic stream of another roadway without affecting safety of the entering vehicle or the vehicle of the other roadway. Refer to appropriate charts in 2001 AASHTO.

Stopping sight distances are usually sufficient to allow alert drivers to come to a stop under ordinary circumstances. However, these distances may be inadequate when:

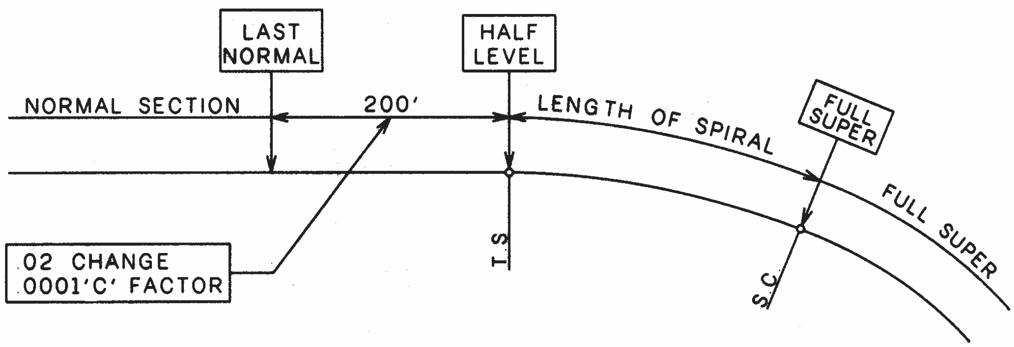
1. Drivers must make complex or instantaneous decisions.
2. Information is difficult to perceive.
3. Unexpected or unusual maneuvers are required.

Decision sight distance shall be considered where these conditions exist. Examples of possible consideration, where these kinds of driver error are likely to occur are:

1. Interchanges and intersections.
2. Locations where unusual or unexpected maneuvers are required.
3. Lane drops.

Where there is likelihood for error in understanding traffic control markings, decision making or driver actions, the decision sight distances shall be considered. If it is not feasible to provide the decision sight distance, special attention shall be given to the use of suitable traffic control devices for providing advance warning of the condition to be encountered.

DESIGN AND SUPERELEVATION OF SPIRAL CURVES FOR MAINLINE EXPRESSWAYS ONLY



LENGTH OF SPIRAL = SUPER RATE ÷ 'C' FACTOR

USING A 'C' FACTOR OF .0001, THE FOLLOWING LENGTHS APPLY:

WHEN S =	.08	- USE	800' SPIRAL
" "	.06	"	600' "
" "	.04	"	400' "
" "	.02	"	200' "

HALF LEVEL OCCURS AT THE T.S. and S.T. STATIONS

FULL SUPER EXTENDS FROM THE S.C. TO THE C.S. STATION.

NORMAL SECTION IS 200' BEYOND T.S. and S.T. STATIONS

(C = .0003)

REFER TO HICKERSON OR BARNETT BOOKS FOR SPECIFIC CURVE DATA. ALSO SEE COMPUTER UNIT PERSONNEL FOR SIMPLIFIED METHODS OF SETTING SPIRAL CURVES USING THE COMPUTER.

NOTE: SPIRAL WILL NOT BE USED ON INTERCHANGE RAMPS INCLUDING DIRECTIONAL RAMPS.

FIGURE HA-1

HIGHWAY POLICIES AND PROCEDURES MANUAL

	Maryland Department of Transportation **STATE HIGHWAY ADMINISTRATION** **Office of Highway Development** **Highway Design Division**	Director, Highway Development
Chapter	DESIGN	**Ref. No.**: D-92-02TS
Section	TYPICAL SECTIONS	**Effective:**
Subject	TRAFFIC BARRIER ‘W’ BEAM END TREATMENT	**Sheet:** 1 **of** 12

Application:
☒ DESIGN
☒ CONSULTANT ENGINEERING
HYDRAULICS
☒ ENGINEERING SUPPORT
ADMINISTRATION
OTHER

Directive: It is the policy of the State Highway Administration to install traffic barrier end treatments on the ends of existing and proposed ‘w’ beam or concrete traffic barriers for all highway projects on the National Highway System (NHS), that meets Federal regulations.

Purpose: This directive provides guidance in the selection or method of treating the ends of ‘w’ beams or concrete shape traffic barriers.

Application: On all construction projects, the appropriate traffic barrier end treatment upgrades shall conform to the guidelines shown in Chart D-92-2TS-1.

Traffic barrier end treatments shall be installed as indicated on Flowcharts D-92-2TS-1 through 4 within this section. It should be noted that the flowcharts are guides and the user may find that all conditions are not covered.

Maintenance of traffic. Temporary traffic barrier end treatments shall be utilized during construction as indicated in Flowchart D-92-2TS-4. It shall be verified, that when using the appropriate end treatment, sight distance is not impaired.

TYPE OF WORK	FUNDING	GUIDELINES FOR END TREATMENTS
New Construction	70-72	All end treatments must meet current Standards.
3R (Resurfacing/Safety) Freeway	77	All end treatments must meet current Standards.
Non-Freeway	77	If a high speed & high volume roadway, all end treatments must meet current Standards.(a)(b)
Noise Abatement	26	All end treatments must meet current Standards.
Reconstruction Geometric Improvements Intersection Improvements	76 83 84	If the existing traffic barrier is disturbed or within a high speed & high volume roadway, the end treatment must meet current Standards.(a)
Bridge	80	If the existing traffic barrier is disturbed, the end treatment must meet current Standards
Maintenance	14	If the existing end treatment has been struck and damaged beyond repair, its replacement must meet current Standards.
Landscape/Streetscape C.H.A.R.T. Wetland Replacement Rideshare Reconstruct R/R X-ing Rest Area/Information Bridge Painting Miscellaneous (Slide repair, Drainage, Safety, and Lighting) Preventive Maintenance		Does not require replacement of existing end treatments

(a) High speed is ≥ 45 mph posted speed & high volume is > 10,000 ADT (existing traffic count)
(b) High speed & low volume on NHS, use compliant end treatment

Chart D-92-2TS-1 Guidelines for traffic barrier end treatment upgrades

Definitions:

Gating. The characteristic of an end treatment that would allow a vehicle impacting the nose of the unit at an angle to pass through the device.

Non-Gating. The characteristic of an end treatment that indicates that the unit will bring an impacting vehicle to a controlled stop after an angled nose impact.

High Accident Location. A location (intersection, spot or road segment) identified through a formal process as having a significantly higher accident frequency, rate and/or severity over a given period of time than that for similar locations, and as meriting specific consideration for remedial measures.

Type A End Treatment. Type A is the most preferred end treatment. The semi-rigid system is buried in the cut slope (see MD 605.01 and MD 605.01-01, -02, & -03). Apply proper flare rate of 12.5:1 to barrier.

Type B End Treatment. Type B (see MD 605.02) is used with single 'w' beam barrier. This gating system requires a 4 ft parabolic flare and should be used with sufficient grading. It may be used on the outside and in the median when there is sufficient clear area behind the system.

Type C End Treatment. Type C (see MD 605.03 and MD 605.04) is a single 'w' beam gating system designed to require no flare from the roadway. It may be used on the outside and in the median when there is sufficient clear area behind the system.

Type D End Treatment. Type D (see MD 605.05) is a double 'w' beam parallel gating system. It may be used in medians and in some gore applications where gating is not a major concern. Transitions to the concrete barrier are available for this end treatment. It may be used as an alternate to the Type F End Treatment when conditions are equal in application.

Type E End Treatment. Type E (see MD 605.06 & MD 605.06-01) is a non-gating system. This end treatment can be used with double 'w' beam or concrete barrier and is beneficial for narrow median applications.

Type F End Treatment. Type F (see MD 605.07) is a double 'w' beam parallel non-gating system. This system can be used in the median and gore areas. It is also beneficial in rock areas and may be used as an alternate to the Type D End Treatment when conditions are equal in application. Transitions to the concrete barrier are available for this end treatment.

Type G End Treatment. Type G is a single beam turn down treatment and may be used on traffic barrier when posted speeds are 40 mph or less (see MD 605.08 and MD 605.08-01). This system may be used on top of curbed sections.

Type H End Treatment. Type H is a double beam turn down treatment and may be used on traffic barrier when posted speeds are 40 mph or less (see MD 605.09). This may be used on top of curbed sections.

Type I End Treatment. Type I is a single beam treatment for terminating the trailing end of traffic barrier where there is no opposing traffic within 30 ft of the barrier. It may be used on entrances to terminate a radius beam panel (see MD 605.10 and MD 605.10-01).

Type J End Treatment. Type J (see MD 605.11) is a reusable system that has a minimal repair time and can take several hits without damage to the structural integrity of the components. This system may be used on high speed, high volume unidirectional locations. It may be used with double ‘w’ beam or concrete barrier. This non-gating system may also be used as an alternate to Type E when conditions are equal in application.

General:

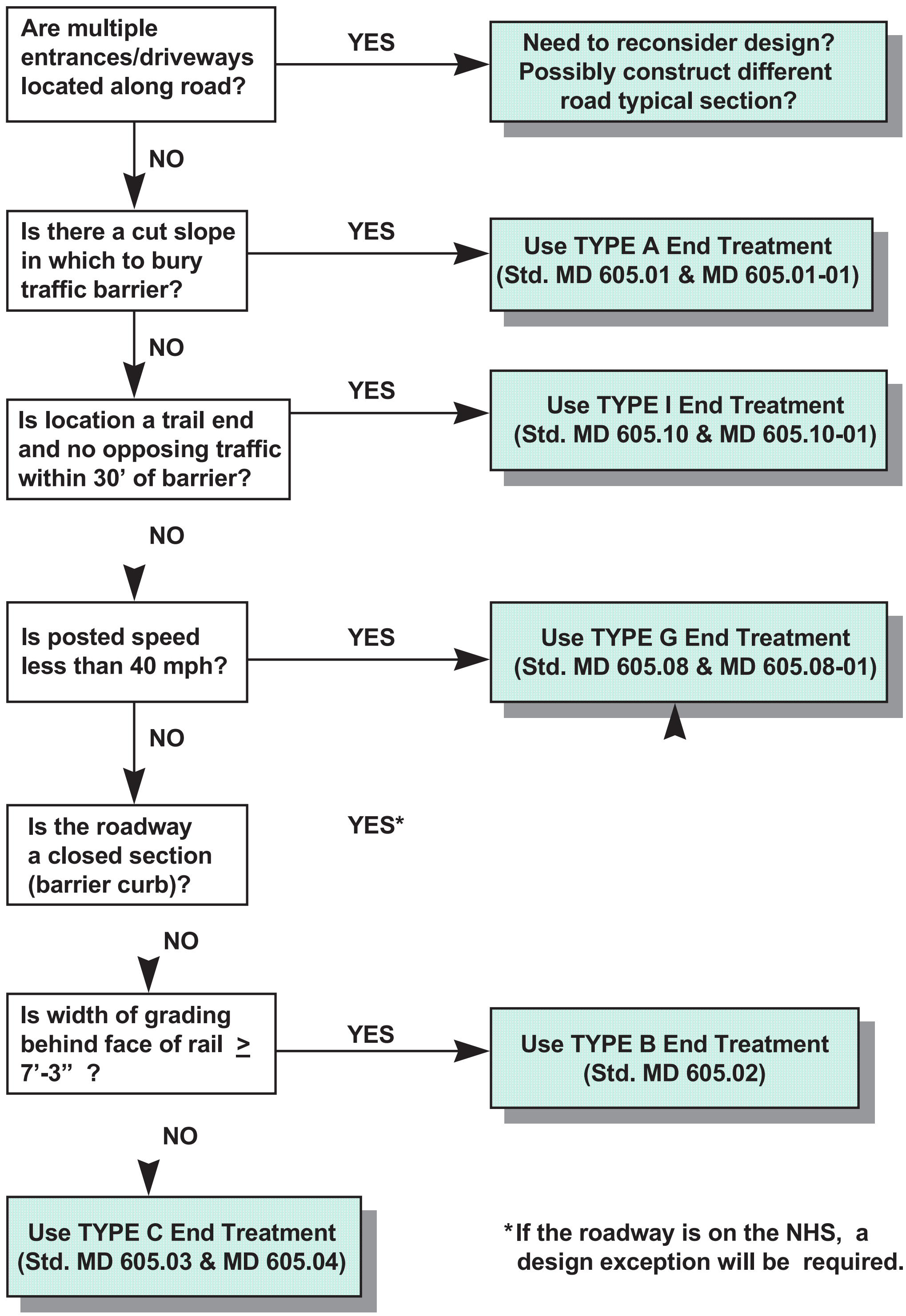
1. When two end treatments are within 200 ft of each other it may be more cost effective to join these sections of traffic barrier.

2. Careful attention shall be given to the placement of end treatments so that they do not impede maintenance operations.

3. It is important to provide the necessary approach surface grading adjustment for barrier end treatments so the system can operate at its maximum potential.

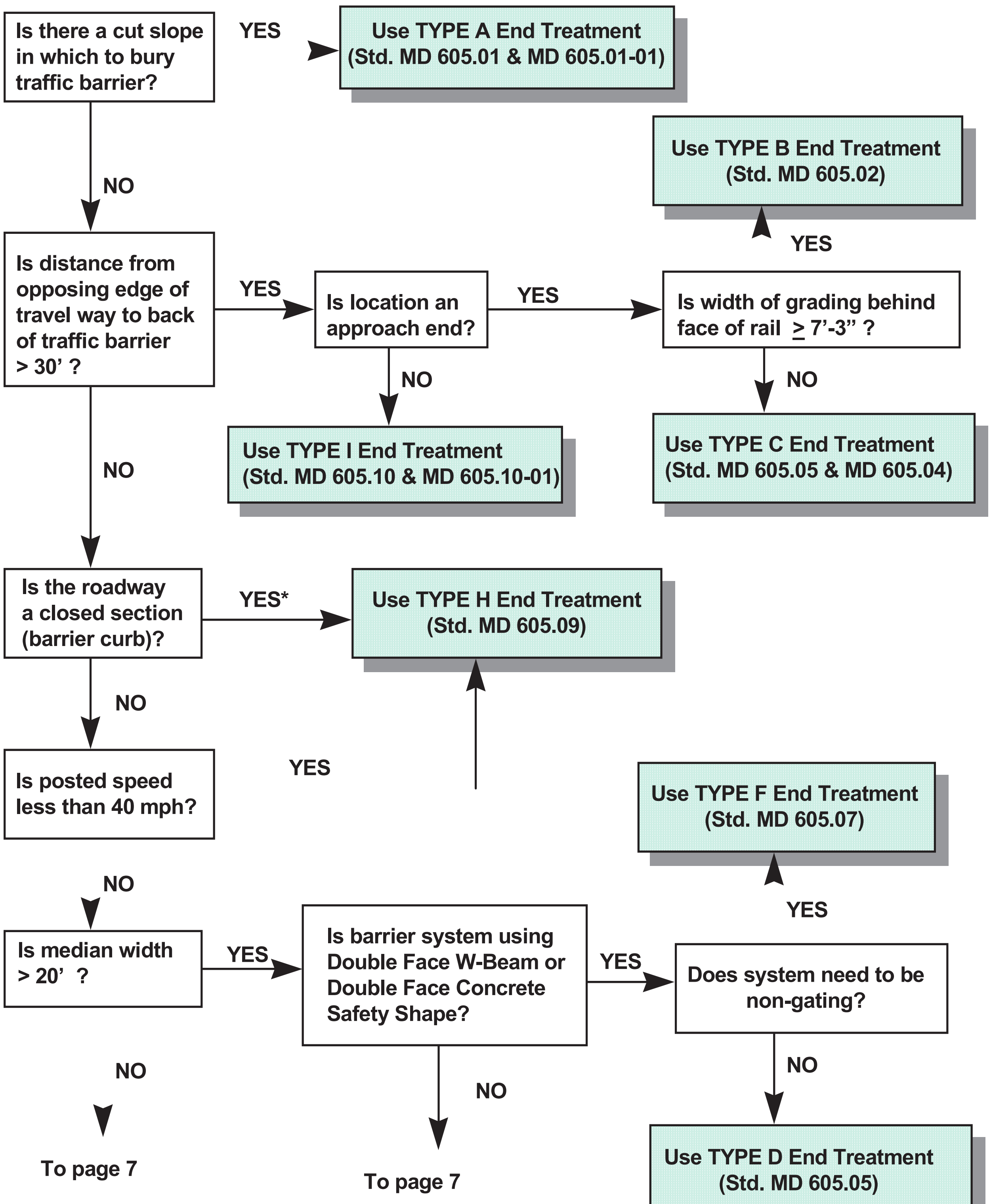
4. Type B, C, D, E, F, and J End Treatments shall not be placed next to or on top of curbed sections.

5. Engineering judgment shall be used to evaluate the feasibility of adjusting the length of the traffic barrier to utilize the Type A End Treatment (bury in cut slope).

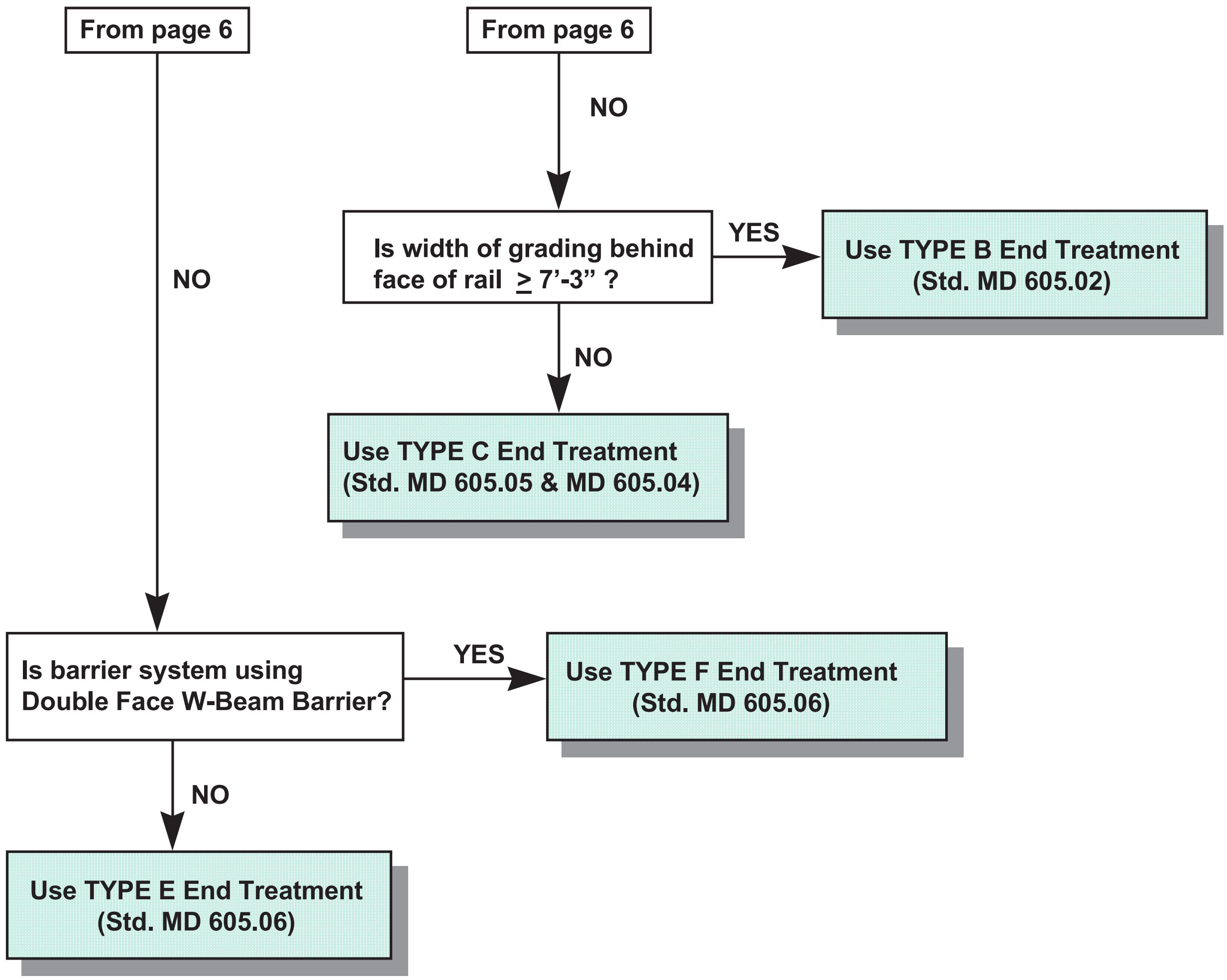


Flowchart D-92-2TS-1
Roadside End Treatments

Provide necessary grading adjustments for end treatments to allow system to operate at maximum potential

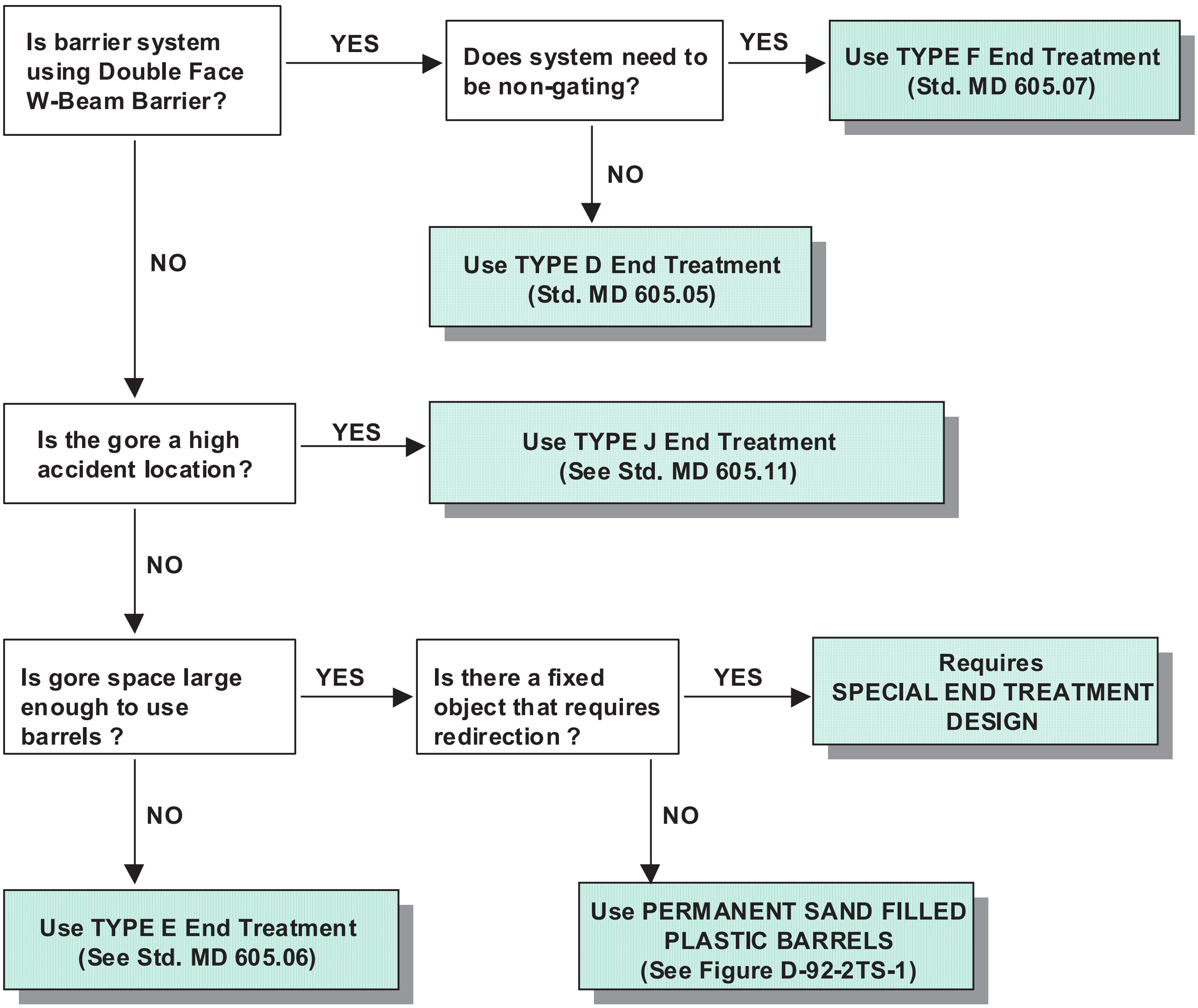


Flowchart D-92-2TS-2
Median End Treatments



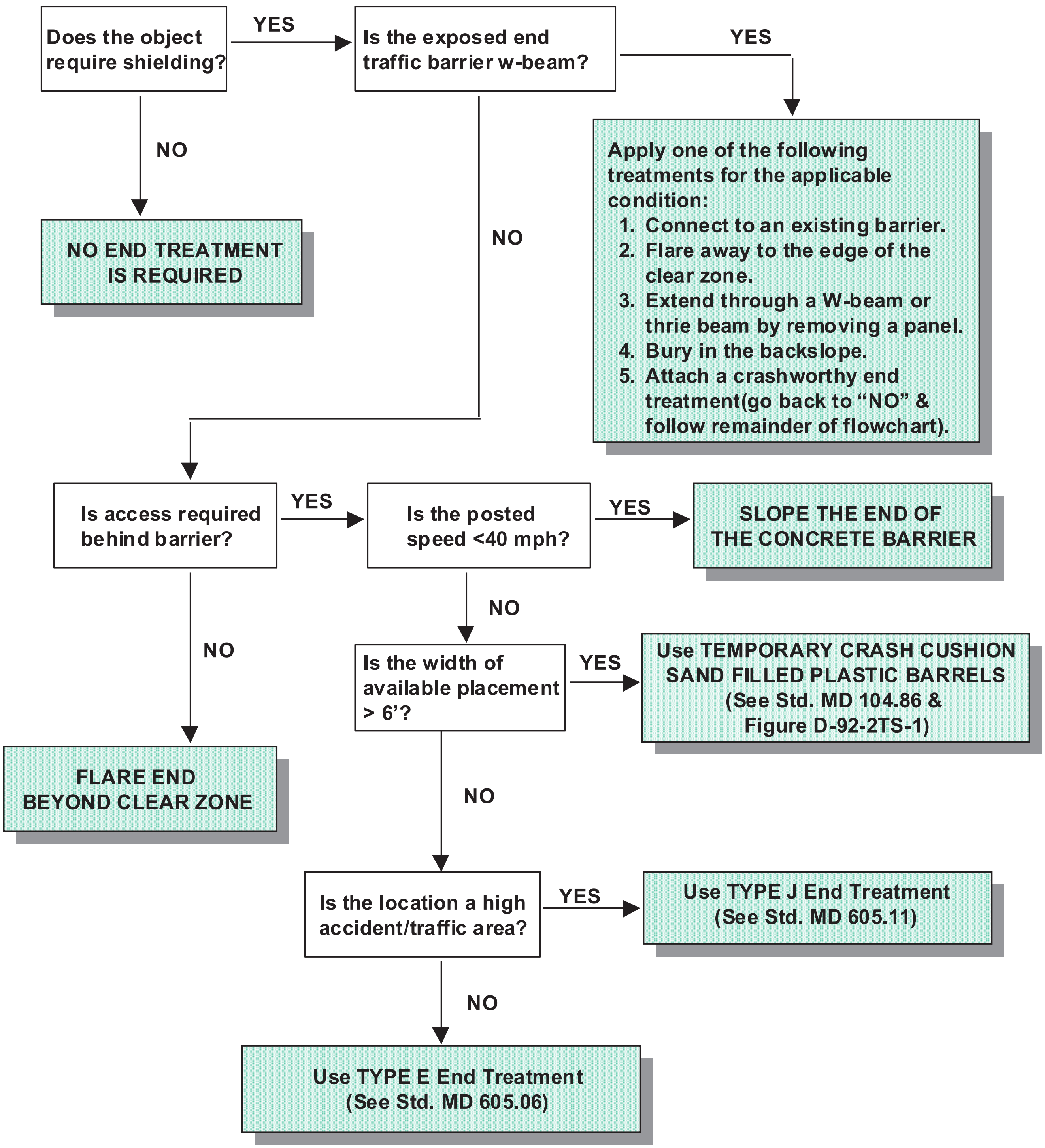
Flowchart D-92-2TS-2 cont'd.
Median End Treatments

Provide necessary grading adjustments for end treatments to allow system to operate at maximum potential



Flowchart D-92-2TS-3
Gore End Treatments

Provide necessary grading adjustments for end treatments to allow system to operate at maximum potential



Flowchart D-92-2TS-4
Maintenance of Traffic
End Treatments

Provide necessary grading adjustments for end treatments to allow system to operate at maximum potential

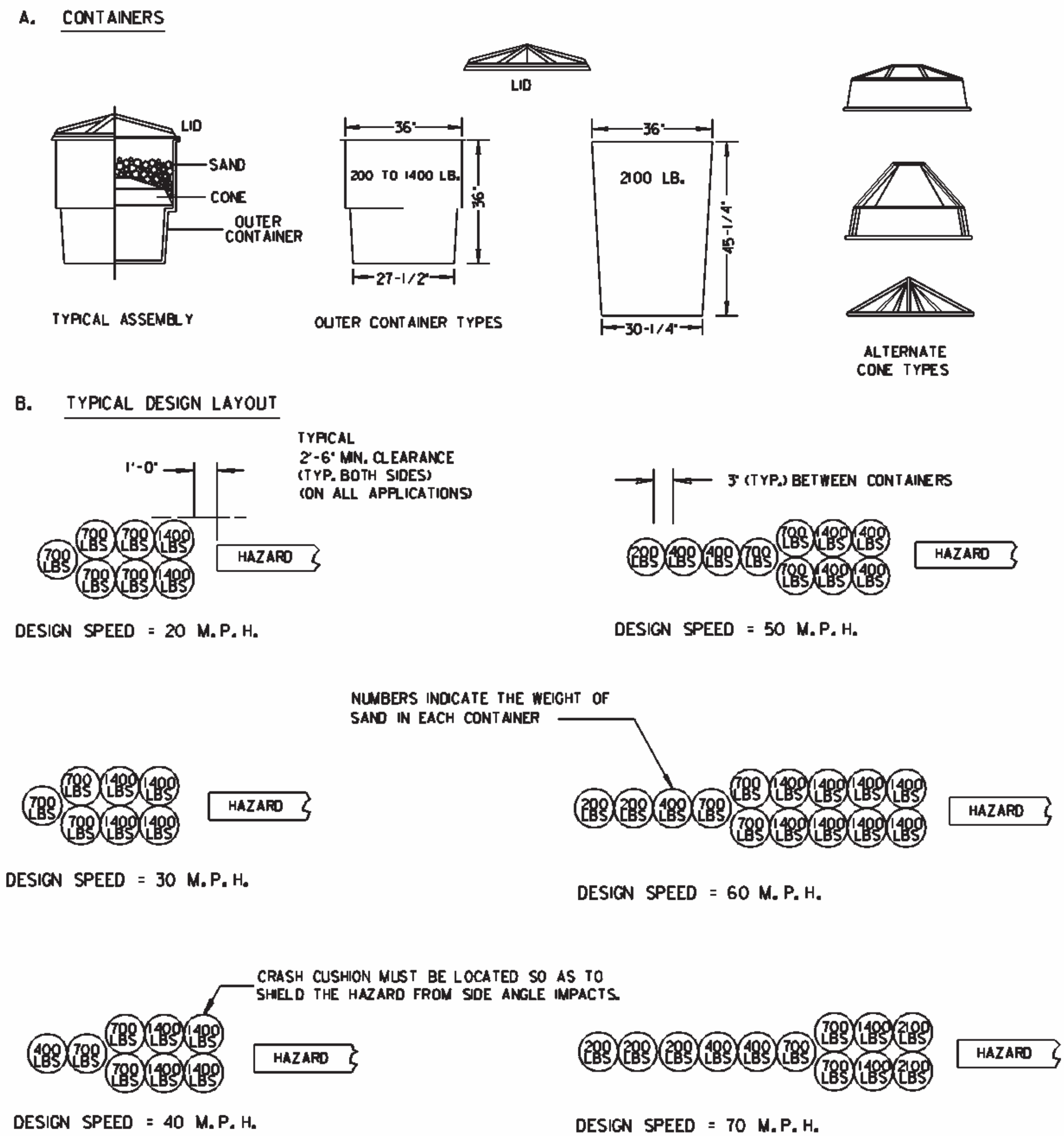


Figure D-92-2TS-1

ROADSIDE				
END TREATMENT (MD Std. No.)	**BARRIER SYSTEMS**	**GRADING REQUIREMENTS**	**APPLICATIONS**	**ESTIMATED COSTS**
Type A MD 605.01 & MD 605.01-01	Single ‘w’ beam	Bury in cut slope	Open sections any posted speed	$-$$$
Type B MD 605.02	Single ‘w’ beam	7’-3” @ 10:1 Maximum slope	Open sections > 40 mph posted speeds	$$
Type C MD 605.03 & MD 605.04	Single ‘w’ beam	3’-3” @ 10:1 Maximum slope	Open Sections > 40 mph posted speeds	$$$
Type G MD 605.08 & MD 605.08-01	Single ‘w’ beam	Approximately 6 ft @ 6:1 or flatter	Open sections ≤ 40 mph posted speeds & closed sections any speed	$
Type I MD 605.10 & MD 605.10-01	Single ‘w’ beam	None	Open & closed sections, non-approach ends @ any posted speed	$

MEDIANS				
END TREATMENT (MD Std. No.)	**BARRIER SYSTEMS**	**GRADING REQUIREMENTS**	**APPLICATIONS**	**ESTIMATED COSTS**
Type A MD 605.01 & MD 605.01-01	Single ‘w’ beam	Bury in cut slope	Open sections any posted speed	$-$$$
Type B MD 605.02	Single ‘w’ beam	7’-3” @ 10:1 Maximum slope	Medians > 30 ft in width & > 40 mph posted speeds	$$
Type C MD 605.03 & MD 605.04	Single ‘w’ beam	3’-3” @ 10:1 Maximum slope	Medians > 30 ft in width & > 40 mph posted speeds	$$$
Type D MD 605.05	Double ‘w’ beam	10:1 maximum on graded slopes	Medians > 20 ft in width & > 40 mph posted speeds	$$$$
Type E MD 605.06 & MD 605.06-01	Double ‘w’ beam or concrete safety shape	10:1 maximum on graded slopes, 8:1 maximum on paved	Medians ≤ 20 ft in width & > 40 mph posted speeds	$$$$$ depends on # of bays
Type F MD 605.07	Double ‘w’ beam	10:1 max., 6:1 max. when barrier is 12 ft or more from shoulder	Non-gating & > 40 mph posted speeds	$$$$
Type H MD 605.09	Double ‘w’ beam	None	Open sections ≤ 40 mph posted speeds & closed sections any speed	$
Type I MD 605.10 & MD 605.10-01	Single ‘w’ beam	None	Non-approach ends & any posted speed	$

Chart D-92-2TS-2 cont’d.

GORES				
END TREATMENT (MD Std. No.)	**BARRIER SYSTEMS**	**GRADING REQUIREMENTS**	**APPLICATIONS**	**ESTIMATED COSTS**
Type D MD 605.05	Double 'w' beam	10:1 maximum on graded slopes	Where 2 rails of 'w' beam converge &> 40 mph posted speeds	$$$$
Type E MD 605.06 & MD 605.06-01	Double 'w' beam or concrete shape	10:1 max. On graded slopes, 8:1 max. On paved surfaces	Non-gating, narrow gores & > 40 mph posted speeds	$$$$$ depends on # of bays
Type F MD 605.07	Double 'w' beam	10:1 maximum on graded slopes	Where 2 rails of 'w' beam converge & > 40 mph posted speeds	$$$$
Type J MD 605.11	Double 'w' beam or concrete shape	10:1 max. On graded slopes, 8:1 max. On paved surfaces	Multiple hit locations, reusable & > 40 mph posted speeds	$$$$$$ depends on # of bays

MAINTENANCE OF TRAFFIC				
END TREATMENT	**BARRIER SYSTEMS**	**GRADING REQUIREMENTS**	**APPLICATIONS**	**ESTIMATED COSTS**
Type E MD 605.06 & MD 605.06-01	Double 'w' beam or concrete shape	Paved surface or concrete base	2 ft min. width & > 40 mph posted speeds	$$$$
Type J MD 605.11	Double 'w' beam or concrete shape	Paved surface or concrete base	4 ft min. width & > 40 mph posted speeds	$$$$$$ depends on # of bays
Temporary Crash Cushion Sand Filled Plastic Barrels MD 104.86	Double 'w' beam or concrete shape	Paved or concrete surface	3-6 ft min. width & any posted speed	$-$$$$ depends on # of barrels
Refer to Roadside Design Guide 9.1.1.4 for additional treatments	Double 'w' beam or concrete shape	Paved or concrete surface	Varies	