

CHAPTER 10

ROADSIDE SAFETY

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INTRODUCTION

A crash may or may not occur if a vehicle leaves the roadway. The severity of this type of crash may be influenced by the physical characteristics of the roadside environment. The Engineer has the ability to minimize the number and severity of crashes by designing roads with proper geometric design and by eliminating, relocating, modifying, and shielding hazardous roadside obstacles. Flat, traversable, stable slopes will minimize overturning crashes. Elimination of roadside hardware, relocation to less vulnerable areas, or uses of breakaway-type devices remain the options of choice in the development of safer roadsides. Roadside obstacles that cannot be otherwise treated should be shielded by properly designed and installed traffic barriers or crash attenuators if it is cost-effective to do so. If a fixed object or other roadside obstacle cannot be eliminated, relocated, modified, or shielded for whatever reason, consideration should be given to delineating the feature, so it is readily visible to a motorist. For further information regarding roadside safety, refer to the current AASHTO publication of the *Roadside Design Guide*.

In this chapter there is general documentation regarding how barrier is typically designed for the National Highway System (NHS) and state routes in South Dakota. The chapter also includes pipe end treatment design information as well as appendices which cover topics about differences between National Cooperative Highway Research Program (NCHRP) Report 350 crash testing standards and Manual for Assessing Safety Hardware (MASH) crash testing standards, flowcharts to help determine whether to use systems that meet crash testing standards of NCHRP 350 or MASH, miscellaneous information regarding the AASHTO/FHWA Joint Implementation Agreement for the AASHTO Manual for Assessing Safety Hardware, and the SDDOT Process for Determining Crashworthiness of Roadside Safety Hardware used on the NHS.

BARRIER DESIGN

Ideally, the recovery area or "clear zone" should be free of obstacles such as unyielding signs and luminaire supports, non-traversable drainage structures, utility poles, and other obstacles as listed under the CLEAR ZONE section. If these obstacles cannot be relocated, removed, or have an appropriate breakaway device then barrier would typically be required.

Several items must be acquired before it is determined what type of barrier, if any, is needed to protect the traveling public from an obstacle or slope. These items include traffic volumes, barrier design speed (the posted speed), type of roadway (NHS, Non-NHS, Local Road), roadway characteristics (divided, non-divided, lane widths, shoulder widths, median width, steepness of slopes, and offset of beginning and ending of steep slopes), and offset to the obstacle.

The most effective barrier that should be used is the barrier that meets the proper crash test level of MASH or of NCHRP 350 when no MASH devices are available, is cost effective for the particular site, and is the proper barrier based on the barrier design characteristics (for example: amount of allowable deflection distance, embankment needs, allowable variations, maintenance issues, barrier would perform reasonably well at the particular site, and others). See section regarding BARRIER TYPES, Appendix A, Appendix B, and Appendix C.

BARRIER DESIGN STEPS

The graphical method is preferred to determine the required barrier lengths to install. See the section for BARRIER DESIGN EXAMPLES and current AASHTO publication of the *Roadside Design Guide* for examples of barrier design. The following is a suggested list of steps for barrier design:

1. Determine if barrier is required.
 - a) Assemble roadway data which will include: the roadway posted speed, the directional average annual daily traffic (AADT), the roadway characteristics (lane widths, roadway shoulder widths, and the structure shoulder widths when structures are involved). See sections on AVERAGE ANNUAL DAILY TRAFFIC (AADT) and BARRIER DESIGN SPEED.
 - b) Determine the clear zone width which will vary depending on the type of project, type of roadway, and design speed. See sections on CLEAR ZONE and LATERAL OFFSET.
 - c) If there is an obstacle within the clear zone, then barrier design is typically necessary.
2. Determine the lateral distance to the roadside obstacle. This distance is the distance from the edge of the traveled way to the far side of the obstacle or to the outside edge of the clear zone (whichever is less). For the outside shoulders, it will be the distance to the obstacle or the clear zone. For median shoulders, the lateral distance will be 40' or in the case of twin bridges to the corner of opposing bridge (max 80').
3. Determine the runout length using Table 10-9. The runout length is the distance from the upstream extent of the obstruction being shielded to the location at which a vehicle is assumed to leave the roadway. The runout length is needed to determine the barrier length of need. To determine the runout length, two criteria are required, the barrier design speed (posted speed) and the directional AADT.
4. Draw the "Protection Line" from the lateral distance point of the roadside obstacle (see step 2) to the edge of nearest traveled way using the runout length (see DESIGN EXAMPLES).

5. Determine which type of barrier to use for protecting the traveling public from the roadside obstacle. See section on BARRIER TYPES, Appendix A, Appendix B, Appendix C, and current AASHTO publication of the *Roadside Design Guide*.
6. If it is necessary to flare the barrier then do so using the flare rate in Table 10-9. See the section on FLARE RATE. The flare rate is the rate at which a barrier flares away from the roadway.
7. Graphically layout the guardrail using the barrier type necessary (Must use cells from the current cell library available from the SDDOT downloadable files web page) and make sure it is terminated with an approved end terminal. See section for BARRIER DESIGN EXAMPLES and BARRIER TYPES.
8. Dimension the drawings for the guardrail layout, and verify that all payment lengths are correct, match Standard Plates, and match bid item descriptions. Label and specify the information regarding special needs. See section for BARRIER DESIGN EXAMPLES. Note: all dimensions of the guardrail on the guardrail layout sheet must be parallel to the guardrail as the guardrail length is measured at the face of the rail.

CLEAR ZONE

The clear zone is considered the total roadside border area, starting at the edge of the traveled way available for the safe use by errant vehicles. The clear zone area may consist of an auxiliary lane (low speed, ≤ 40 mph Design Speed), a shoulder, a recoverable slope, a non-recoverable slope and/or clear run-out area. The traveled way is the portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes (low speed, ≤ 40 mph Design Speed).

Adequate clear zone distance between the edges of traffic lanes and roadside obstructions has been shown to be a very important safety factor. Out of control vehicles leaving the roadway should have a reasonable opportunity to recover control without overturning or colliding with roadside obstacles. The combination of a relatively flat slope and an obstacle-free roadside within the prescribed clear zone distance helps this situation.

The following list of roadside obstacles provides guidance for the designer; however, is not all inclusive:

- Bridge piers, abutments, and railing ends
- Boulders
- Trees
- Cross (transverse) pipe opening widths larger than 30 inches
- Box culverts and cattle passes
- Approach (parallel) pipe height larger than 24 inches
- Permanent bodies of water - a judgment decision based on location, depth of water, and likelihood of encroachment

- Cut slopes (rough)
- Inslopes steeper than 3:1
- Approach slopes steeper than 6:1
- Signs/luminaires/traffic signals with non-breakaway supports
- Utility poles
- Walls (unless crashworthy)
- Fill heights
- Other obvious unforgiving obstacles

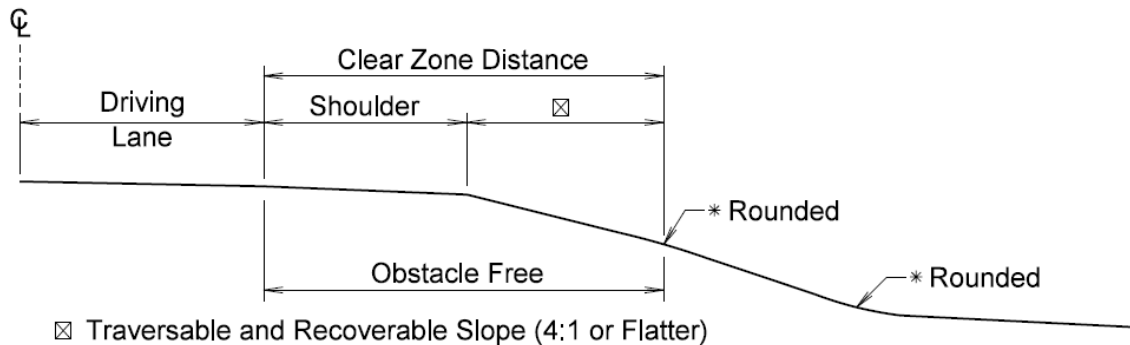
Studies have indicated that on high-speed highways, a width of 30 feet or more from the edge of the through traveled way permits about 80% of the vehicles leaving a roadway out of control to recover and gain control. Considering this and the fact that South Dakota generally has low traffic volumes, South Dakota adopts this distance as the practical distance to either keep obstacle free or to protect with use of a roadside safety appurtenance. However, Resurfacing, Restoration, and Rehabilitation (3R) criteria considers less clear distance to economically provide the citizens of South Dakota a well-maintained highway in its existing condition.

The current SDDOT Local Roads Plan contains the clear zone policy for county on and off system roads. This manual is available from the Office of Administration/Local Government Assistance.

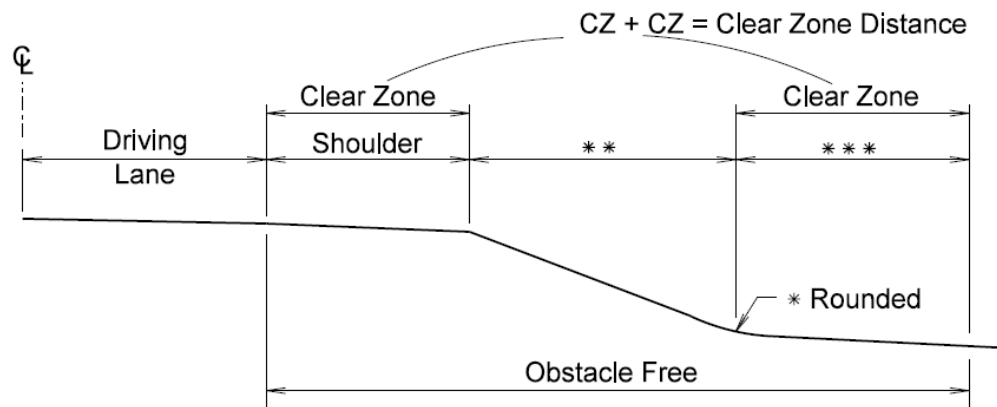
Each project will be reviewed and evaluated for other fixed objects within the highway right-of-way (ROW) area. This evaluation will be done to ensure uniformity throughout a project (route continuity) with regard to fixed objects. For example, if the project is in an area with many trees, some trees left within the ROW may be appropriate. However, in areas that do not have many trees, trees should not be allowed within the ROW area.

There are three exceptions to the clear zone criteria. They are proper barrier systems, SDDOT approved breakaway-type luminaire poles, and SDDOT approved breakaway-type sign posts. All three are permitted within the specified clear zones.

Even when the clear zone criteria have been met, the designer should evaluate other ways where safety could be enhanced. For example, the designer may want to provide a recovery area (Figure 10-1) at the bottom of an area with steep inslopes, if such an area could be provided economically.



☒ Traversable and Recoverable Slope (4:1 or Flatter)



- * The cross sections are typically rounded during construction so the breakpoints in slopes are not as abrupt as drawn in the plans.
- ** Traversable and Nonrecoverable Slope (3:1 to <4:1)
- *** 10' Minimum Traversable and Recoverable Slope (6:1 or Flatter Desirable)

Figure 10-1 Recovery Area and Clear Zone Examples

The following are preferred **Construction/Reconstruction** clear zones:

- for high speed (≥ 55 mph Design Speed) highways (including Interstates) with or without curb and gutter, a 30-foot clear zone should be used. See the following two exceptions for the 30-foot clear zone.
 - On divided highways, a median barrier design should protect the opposing bridge end when the median width is 80 feet or less as measured from the edge of opposing traveled ways. When median widths exceed 80 feet, use 80-foot clear zone. See DESIGN EXAMPLE 1.
 - For Interstate medians, a 40-foot clear zone should be used at bridge column/pier locations. See DESIGN EXAMPLE 2.
- for intermediate speed (45 to 50 mph Design Speed) highways with or without curb and gutter, engineering judgment will be used to determine the clear zone. For these intermediate speed roadways, designers should consider a clear zone up to 30 feet measured from the edge of traveled way. The designer should calculate the clear zone based on design speed, design AADT, and slopes using Table 3.1 of the current AASHTO publication of the *Roadside Design Guide*. The clear zone used should be documented in the scope of the project as per Chapter 2 – Scope Process and Project Management.
- for low speed (≤ 40 mph Design Speed) highways with or without curb and gutter, lateral offset will be utilized in place of clear zone. See the section regarding LATERAL OFFSET.

The following are preferred 3R clear zones:

- for all non-interstate projects where the highway has previously been regraded to AASHTO standards and completed after 1971, a clear zone of 30 feet should be used when the existing guardrail design used a 30-foot clear zone or greater.
- for interstate and shoulder widening projects use construction/reconstruction clear zone standards.
- for high-speed (≥ 55 mph Design Speed) projects with or without curb and gutter which do not fit within the described bullet above, Tables 10-1 and 10-1A are used for determining clear zone.

Table 10-1 Clear Zone for 3R Projects on National Highway System

Existing Traffic Volume (Total AADT)	Clear Zone (Ft.)
< 551	10
551 to 1500	15
1501 to 2500	20
> 2500	30

Table 10-1A Clear Zone for 3R Projects Other Than National Highway System

Existing Traffic Volume (Total AADT)	Clear Zone (Ft.)
< 551	10
551 to 1500	15
> 1500	20

- for intermediate speed (45 to 50 mph Design Speed) projects with or without curb and gutter, engineering judgment will be used to determine the clear zone. For these intermediate speed roadways, designers should consider a clear zone up to 30 feet measured from the edge of traveled way. The designer should calculate the clear zone based on speed, ADT, and slopes using Table 3.1 of the current AASHTO publication of the *Roadside Design Guide*. The clear zone should not be greater than what is shown in Tables 10-1 and 10-1A for the same ADT.
- for scenic or recreational routes as defined by the policy DOT-P&E-PD-6.0 (\leq 40 mph Design Speed) a minimum clear zone of 4 feet should be considered.
- for low speed (\leq 40 mph Design Speed) highways with or without curb and gutter lateral offset will be utilized in place of clear zone. See the LATERAL OFFSET section for guidance.

The following are preferred 3R clear zones for Interstate Crossroads:

- for high speed (≥ 45 mph Design Speed) local crossroads over/under the Interstate, use Table 10-2

Table 10-2 Clear Zone for Local Crossroads Over/Under the Interstate System

AADT	Clear Zone (Ft.)
< 151 ¹	2
151 to 400	7-10
> 400	Use Table 10-1

¹When AADT is < 151 Guardrail is not usually required. The Designer may use Engineering judgement to install guardrail (i.e. a very high embankment fill which would cause an errant vehicle to roll multiple times).

- for low speed (≤ 40 mph Design Speed) local crossroads over/under the Interstate, a minimum clear zone of 2' should be considered. For projects with curb and gutter (Type B), lateral offset guidelines from will be utilized in place of clear zone. See the section on LATERAL OFFSET.

Note: For Interstate Bridge Reconstruction Over Local Roads, refer to the SDDOT Local Roads Plan.

LATERAL OFFSET

Lateral offset to obstructions should be utilized for urban roadways with low speeds (≤ 40 mph Design Speed). Lateral offset is an area from the back of the curb to the extent necessary where there are no obstructions (trees, utility poles, fire hydrants, etc.) The lateral offset to obstructions is typically used for the following issues:

- to improve horizontal sight distances at intersections and at driveways
- to reduce contact with obstacles from vehicles (i.e. large mirrors, car doors, overhang of cars and trucks)
- to help avoid adverse impacts on vehicle lane position and encroachments into opposing or adjacent lanes
- to improve travel lane capacity

The following are preferred lateral offsets for urban roadways with low speeds (≤ 40 mph Design Speed) measured from the back of curb:

- for construction/reconstruction and all 3R projects, a desirable 5-foot lateral offset is preferred where practical, but a minimum of a 1-foot lateral offset could be considered.
 - Objects meeting these lateral offset requirements may still cause sight distance obstruction and therefore additional consideration may need to be given during design.

On low speed (≤ 40 mph Design Speed) roadways without curb and gutter and shoulder widths less than 4 feet, a minimum lateral offset of 4 feet from the edge of the traveled way should be provided for construction/reconstruction and 3R projects.

It is desirable to provide the 5-foot lateral offset to obstructions on the outside of horizontal curves where there has been a higher crash rate.

It is desirable to maximize lateral offset to obstructions at intersections and driveways for sight distance and off-tracking trucks. See Chapter 12 – Intersections for information regarding sight triangles.

More information about urban roadside design may be found in the current AASHTO publication of the *Roadside Design Guide*.

PIPE END TREATMENTS

The information contained in Tables 10-3 to 10-7 for pipe end treatments should be considered for design of all projects in the Statewide Transportation Improvement Program (STIP). Every effort should be made to keep the pipe outside the clear zone. Exceptions to this information may be granted through the design exception process. On construction projects with divided highways, attempts will be made to eliminate pipe ends in the median where possible and replace with either a Type L Median Drain, Type M Median Drain, or a vertical riser pipe with a Type N Grate.

Refer to South Dakota Standard Plates 450 Series for Concrete and Corrugated Metal Pipe details. Also refer to South Dakota Drainage Manual for additional information.

Table 10-3 Transverse to Mainline Treatment for Pipe Culverts, Box Culverts, and Cattle Passes for Construction/Reconstruction (Non-Interstate)

Relation to Clear Zone ¹	Cross Pipe Size	Type of End Treatment on Cross Pipe
Inside or Outside	24" and 30"	Sloped End without Protective Bars
Inside	36" and Larger Pipe, All RCBC, and All Cattle Passes	Not allowed inside clear zone unless barrier protection is deemed justifiable or ends have protective bars
Outside ONLY	36" through 60"	Flared End ²
Outside ONLY	Larger than 60", All RCBC, and All Cattle Passes	Flared End, Sectional Apron, or Wing Wall depending on structure ²

¹ See section on CLEAR ZONE.

² When the fill slope above the pipe is flatter than a 4:1 inslope, a proper transition length must be provided to attain the flatter inslope. See Chapter 7 – Cross Sections and Standard Plate 120.05 for appropriate inslope transition.

Table 10-4 Transverse Pipes on Resurfacing Projects (Non-Interstate)

Relation to Clear Zone ¹	Cross Pipe Size	Type of End Treatment on Cross Pipe ³	AADT ²	Inslope
Inside and Outside	24" and 30"	Existing remain in place	<1000	3:1 or Flatter
Inside	24" and 30"	Sloped End without Protective Bars	>1000	3:1 or Flatter
Outside	24" and 30"	Existing remain in place	>1000	3:1 or Flatter
Inside	36" and Larger Pipe, All RCBC, and All Cattle Passes	Existing remain in place Object markers only	<1000	3:1 or Flatter
Inside ⁴	36" through 60"	Sloped End with Protective Bars (Consider extension to Clear Zone and Flared End)	>1000	3:1 or Flatter
Inside ⁴	Larger than 60", All RCBC, and All Cattle Passes	Extend to Clear Zone and consider Flared End, Sectional Apron or Wing Wall depending on structure, or do not extend pipe and install protective bars, or install barrier ⁵	>1000	3:1 or Flatter
Outside	Larger than 60", All RCBC, and All Cattle Passes	Existing remain in place	>1000	3:1 or Flatter

¹ See section on CLEAR ZONE.

² AADT is current AADT.

³ See Standard Plates 632.01, 632.03, and 632.04 for Type 2 Object Marker Installation for Pipes, Box Culverts, and Cattle Passes and refer to policy for Road Delineation and Markers for Box Culvert, Pipe Culvert, and Cattle Pass Ends on State Highways.

⁴ Only if cost effective/crash analysis justifies installation. Hydraulics should be reviewed if not extending pipe and protective bars are provided.

⁵ See Chapter 7 – Cross Sections and Standard Plate 120.05 Inslope Transition for appropriate inslope transition.

For existing cross pipes without an end treatment inside the clear zone, an appropriate end treatment should be added.

Table 10-5 Approach Treatment for Construction/Reconstruction (Non-Interstate)

Relation to Clear Zone ¹	Approach Pipe Size	Type of End Treatment on Approach Pipe	Approach Slope
Inside	18" and 24"	Safety End without Protective Bars For multiple pipe installations, protective bars may be considered.	6:1
Outside	18" and 24"	Safety End without Protective Bars	6:1 ²
Inside	30" through 60"	Safety End with Protective Bars	6:1
Outside	30" through 36"	Safety End without Protective Bars Protective bars may be provided where deemed appropriate.	6:1 ²
Outside	42" through 60"	Safety End with Protective Bars ³ Flared ends may be considered if there is measurable cost savings.	6:1 ²
Outside ONLY	Larger than 60"	Flared Ends will be considered or consider smaller multiple pipe and end sections.	6:1 ²

¹ See section on CLEAR ZONE.

² When pipe is installed and where the distance for slope to intercept the original ground is excessive, a 4:1 may be considered as long as a 6:1 is used within the mainline highway clear zone and the intercept point of the approach slope and original ground or ditch profile is rounded as shown in Figure 10-2. The 4:1 may be considered only outside of the clear zone if there is measurable cost savings.

³ Protective Bars to be provided for structural reasons.

Table 10-6 Approaches on Resurfacing Projects (Non-Interstate)

Relation to Clear Zone¹	Approach Pipe Size	Type of End Treatment on Approach Pipe	AADT²	Approach Slope³
Inside or Outside	18" and 24"	Flared Ends may remain in place	>500	6:1 ⁴
Inside	30" and Larger	Consider Safety Ends with bars	>500	6:1 ⁴
Outside ONLY	30" and Larger	Flared Ends may remain in place	>500	6:1 ⁴
Inside or Outside	All Sizes	Flared Ends may remain in place	≤500	6:1 ⁵

¹ See section on CLEAR ZONE.

² AADT is current AADT.

³ As measured within the clear zone.

⁴ Approach slope should be previously flattened to 6:1 or flatter.

⁵ Approach or ditch block slope flattening may not be necessary. Design exception should be approved.

Table 10-7 Pipe Culvert Treatment on Interstate Projects

Location of End Section	Relation to Clear Zone¹	Cross Pipe Size	Type of End Treatment on Cross Pipe	Inslope²
MEDIAN INSLOPES	Inside	18" to 30"	Sloped End without Protective Bars	5:1
	Inside	18" to 30"	Safety End without Protective Bars	6:1
	Inside	36" and Larger	Sloped End with Protective Bars	5:1
	Inside	36" and Larger	Safety End with Protective Bars	6:1
	Outside	All Sizes	Flared Ends may remain in place	NA
OUTSIDE INSLOPES	Inside	18" and 24"	Sloped End without Protective Bars	4:1 or 5:1
	Inside	18" and 24"	Safety End without Protective Bars	6:1
	Inside	30"	Sloped End without Protective Bars	4:1, 5:1, or 6:1
	Inside	36" and Larger	Sloped End with Protective Bars	4:1, 5:1, or 6:1
	Outside	All Sizes	Flared Ends may remain in place	NA
Location of End Section	Relation to Clear Zone¹	Crossover Pipe Size	Type of End Treatment on Crossover Pipe	Transverse Slope²
CROSSOVER TRANSVERSE SLOPES	Inside	18" and Larger	Safety End with Protective Bars	6:1
	Outside	18" and Larger	Safety End without Protective Bars	6:1

¹ See section on CLEAR ZONE.

² As measured within the clear zone.

AVERAGE ANNUAL DAILY TRAFFIC (AADT)

The ADT used for barrier design are as follows:

- Interstate projects should always use 10,000+.
- 3R projects should use the present AADT for current directional AADT (one-way volume). *Example: 2000 current total AADT received from Transportation Inventory Management should be multiplied by the $D=50\%$ where the directional AADT equals 1000.*
- Construction/Reconstruction projects should use the future design AADT counts for future directional AADT (one-way volume).

If the directional AADT is less than 500, consider using the minimum length guardrail. See section on MINIMUM LENGTH GUARDRAIL.

BARRIER DESIGN SPEED

The speed used for barrier design is as follows:

- Interstate projects should use the current posted speed limit.
- Non-interstate projects should use the current posted speed limit for 3R projects or the proposed posted speed limit for Construction/Reconstruction projects.

RUNOUT LENGTH

Determine the runout length using Table 10-8. The runout length is the distance from the upstream extent of the obstruction being shielded to the location at which a vehicle is assumed to leave the roadway. The runout length is needed to determine the barrier length of need. To determine the runout length, two criteria are required, the posted speed of the roadway and the directional AADT.

Table 10-8 Runout Length

Posted Speed mph	Runout Length (Ft.) for Directional AADT ¹			
	Over 10,000	5001 to 10,000	1000 to 5000	Under 1000
80	470	430	380	330
75	415	380	335	290
70	360	330	290	250
65	330	290	250	225
60	300	250	210	200
55	265	220	185	175
50	230	190	160	150
45	195	160	135	125
40	160	130	110	100
35	135	110	95	85
30	110	90	80	70

¹ All mainline Interstates will use 10,000+ directional AADT.

FLARE RATE

Determine the flare rate using Table 10-9. The flare rate is the rate at which a barrier flares away from the roadway. Flares on barriers are used to:

- move the barrier terminal further away from the roadway
- minimize a driver's reaction to an obstacle near the road by gradually introducing a parallel barrier installation
- transition a roadside barrier to an obstacle nearer the roadway such as a bridge railing
- reduce the total length of barrier needed at an installation
- give an errant motorist a reasonable chance of regaining control of the vehicle without crashing into the barrier
- provide better sight distance, particularly at intersections
- help with maintenance issues such as snow drifting and snow removal
- help accommodate snow conditions such as snow storage

Flaring the guardrail beyond the maximum flare rates listed in Table 10-9 will increase the impact angle and severity of crashes, particularly for rigid and semi-rigid barrier systems and must therefore be avoided. Flaring the guardrail within the rates provided in Table 10-9 is preferred to move the barrier as far as practicable from the traveled way, while maintaining the proper operation and performance of the system.

The guardrail transitions attached to structures should not be flared. The point at which the barrier could begin flaring is shown on the Standard Plates for the various transitions.

The shy line is the distance from the edge of traveled way, beyond which a roadside obstacle should not be perceived as an obstacle and result in a motorist's reducing speed or changing vehicle position on the roadway. The shy line location is necessary to use the Flare Rate table.

The highway's outside edge of finished shoulder is considered the shy line on all projects in the State of South Dakota.

The end terminals should typically not terminate inside the shy line. It is recommended that the front face of the rail at the end terminal be a minimum of 4.5 feet from the edge of the traveled way particularly when installing guardrail at structures with a width of 30-foot or less. The designer will need to determine how to obtain this minimum distance by flaring the guardrail, using a tangent end terminal with a maximum flare rate of 25:1, using a flared end terminal, or using a combination of these options while trying to minimize embankment work. There may be some instances where the designer may have to use engineering judgement to determine the most effective solution.

There may be instances when it is acceptable to place crash cushions (attenuators) inside the shy line for narrow structures or median barriers as necessary. The end terminal could be inside the shy line also in cases where minimum length guardrail design is used at a narrow structure.

Table 10-9 Flare Rate*

Posted Speed (mph)	Inside Shy Line (steel beam guardrail and concrete barrier)	Outside Shy Line (steel beam guardrail)	Outside Shy Line (concrete barrier)
80	34:1	18:1	24:1
75	32:1	16:1	22:1
70	30:1	15:1	20:1
65	28:1	14:1	19:1
60	26:1	14:1	18:1
55	24:1	12:1	16:1
50	21:1	11:1	14:1
45	18:1	10:1	12:1
40	16:1	8:1	10:1
30	13:1	7:1	8:1

* Maximum flare rate for all cable barriers is 32:1; however, the flare rate for cable barriers is 34:1 on 80 mph posted speed interstates to match the maximum flare rate for steel beam guardrail and concrete barrier inside the shy line.

INSLOPES

For more detail on Inslopes refer to Chapter 7 – Cross Sections.

Fill slopes steeper than 3:1 are non-recoverable and non-traversable; therefore, they are considered roadside obstacles in South Dakota.

- Slopes designed steeper than 3:1 within the clear zone should be protected with barrier.
- A fill slope between a 3:1 and 4:1 is considered traversable, but non-recoverable, therefore, obstacles should be removed from the non-recoverable slope as well as the recoverable slope at the toe of the inslope. If a traversable slope terminates within the total clear zone width, a clear recoverable area should be provided at the toe of the slope. The width of the clear recoverable area is equal to the portion of the clear zone distance that is located on the non-recoverable slope. A minimum recoverable width of 10 feet is desirable or barrier should be installed. See drawings in Figure 10-1.
- Fill slopes 4:1 or flatter are recoverable and traversable, so if no obstacle is located within the clear zone, barrier does not need to be provided.

Transverse slopes are embankment slopes created by intersecting roads, median crossovers, entrances, and ditch blocks. When a pipe is required to carry water through any one of the above items, a slope of 6:1 is used. When a pipe is not required, a 10:1 slope is used. In cases of high fill the 10:1 slope may be steepened if deemed appropriate, but should never be steeper than 6:1.

Attention should be given to situations where a steep ditch profile intersects the fill slope of an entrance adversely. Such circumstances may warrant a rounding of the ditch grade as shown in Figure 10-2 which reduces the chances of an errant vehicle becoming airborne, reduces the chance of snagging a bumper, and affords the driver more control of the vehicle.

Attention should be given to bicycle and pedestrian facility pathways placed parallel to roadways, especially for design speeds ≥ 55 mph, as the flatter area placed within the inslope could cause vehicles to become airborne or to become unstable. It is preferred that the pathway be installed outside of the clear zone.

Approaches on the outside of horizontal curves should be considered for removal if feasible based on a project by project basis and crash history review.

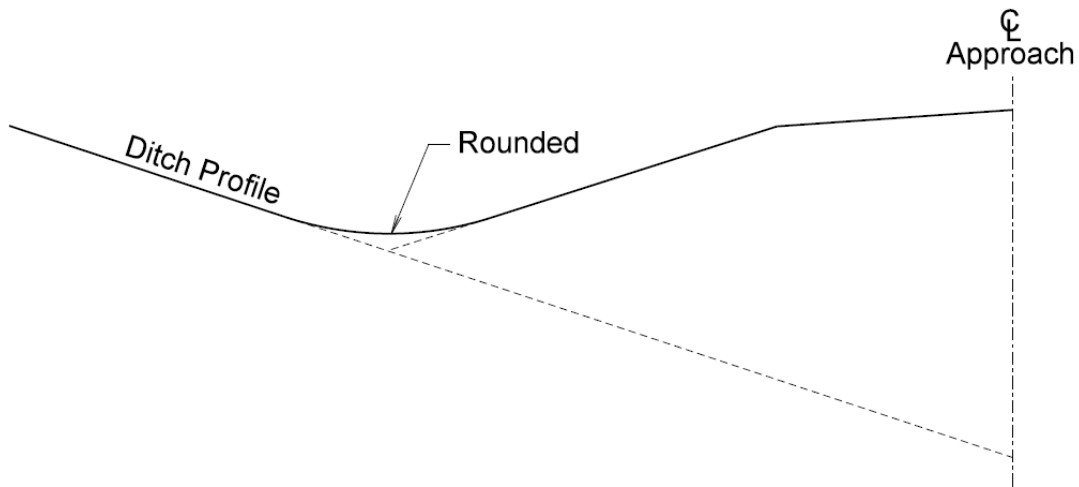


Figure 10-2 Rounding of the Ditch Grade

FILL HEIGHT AND INSLOPES FOR 2R AND 3R PROJECTS

For 2R projects, the review of inslope flattening and guardrail placement recommendations should be done. Figures 10-3 and 10-4 were prepared for 2R projects based on the current AASHTO publication of the *Roadside Design Guide*.

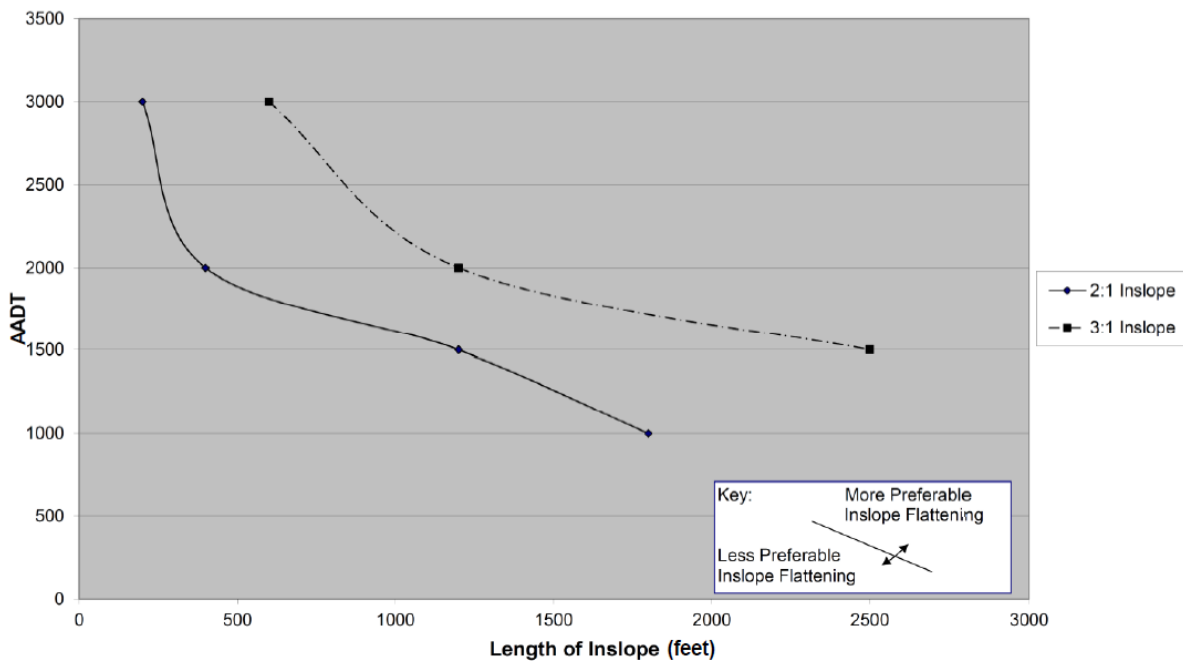


Figure 10-3 Inslope Flattening

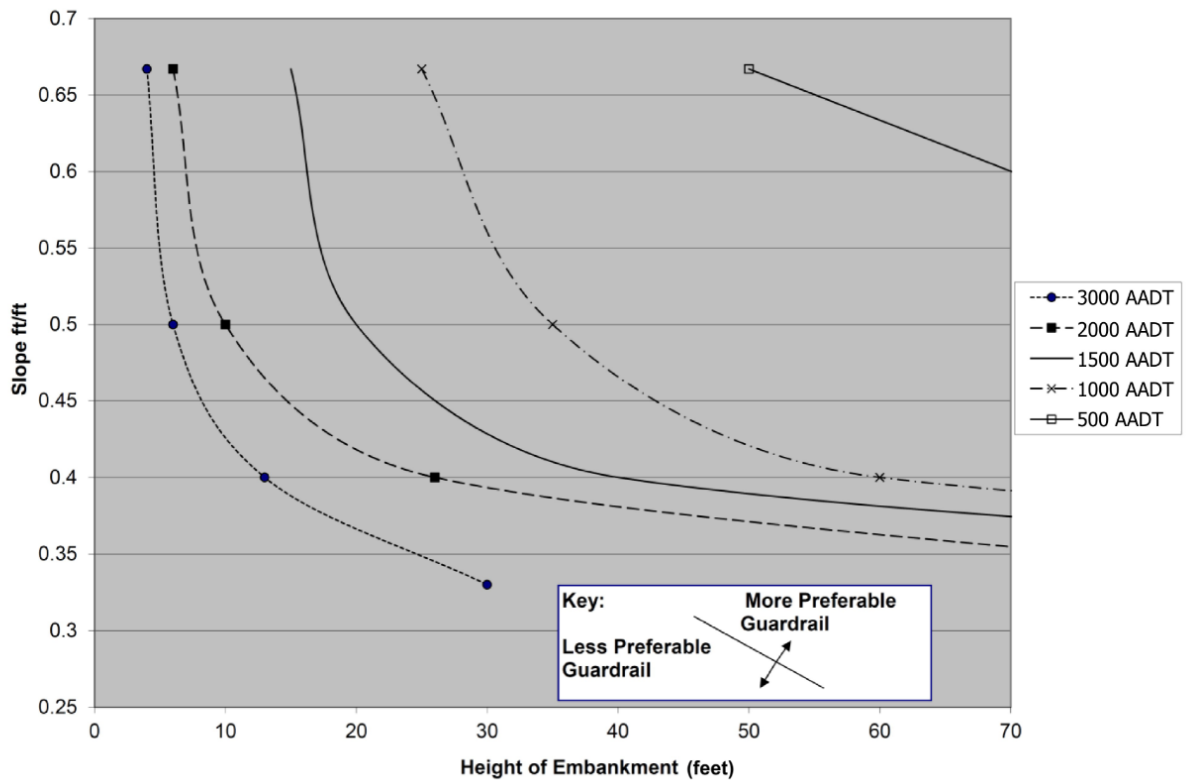


Figure 10-4 Guardrail at Inslopes

For 3R projects the following are guidelines in regard to slope flattening and protecting inslopes (AADT is existing traffic volume):

- AADT \leq 1000, if inslope is steeper than a 3:1, it is not considered cost effective to flatten inslopes or provide guardrail unless crash patterns indicate a problem. However, an inslope steeper than 2:1 for more than 1000 feet of continuous length should be addressed by a design exception if it is not improved.
- AADT $>$ 1000, if fill height is greater than 10 feet and inslope is steeper than a 3:1, inslope flattening or providing guardrail should be considered.

CURBS

The two general classes of curbs are vertical curbs and sloping curbs. SDDOT typically uses only sloping curbs. For a more detailed discussion on curb types, see Chapter 7 – Cross Sections.

When curb and gutter is installed off the ends of bridges and new drop inlets are used, the drop inlets should be placed away from the bridge end at a proper location between the required guardrail post spacing. The drop inlet design, if possible, should be deep enough such that the outlet pipe will have at least 1 foot of clearance between the top of cross pipe to the bottom of a guardrail post. See section on GUARDRAIL TRANSITIONS.

Type B Curb and Gutter is limited to urban areas with speeds of 40 mph or less. Type F Curb and Gutter can be used with speeds greater than 40 mph.

Guardrail designs adjacent to gutter or curb and gutter vary depending on the posted speed and curb type.

- Posted speed limit greater than 40 mph:

Cable Guardrail is not allowed adjacent to any curbs except P Gutter.

Type 4 MGS may be used with type D gutter. Further MASH crash testing needs to occur before using with type B curbs and type F curbs. The face of the steel beam rail of the Type 4 MGS must align with the face of the curb.

Only MGS MASH tangent end terminals will be used adjacent to P gutter. See Figure 10-5.

Single thrie beam guardrail should not be used with curbs until further MASH crash testing and SDDOT approval has occurred.

It is assumed that double (nested) thrie beam guardrail may be used with curbs if the post spacing is 1'-6 ³/₄" (posts are 6"x8"x7'-0" and blockouts are 6"x8"x19") and transition to and from the double rail is similar to the Type 1 Guardrail Transition. Another option is the double (nested) thrie beam for the Type 3 Guardrail Transition (post spacing of 3'-1 ¹/₂", posts are 8"x10"x6'-6" and blockouts are 6"x8"x19") and the rail would have to transition to and from the double rail similar to the transition shown in the Type 3 Guardrail Transition. Double (nested) thrie beam was a part of the MASH crash testing of the transition attached to a concrete bridge rail end block. See Figure 10-6.

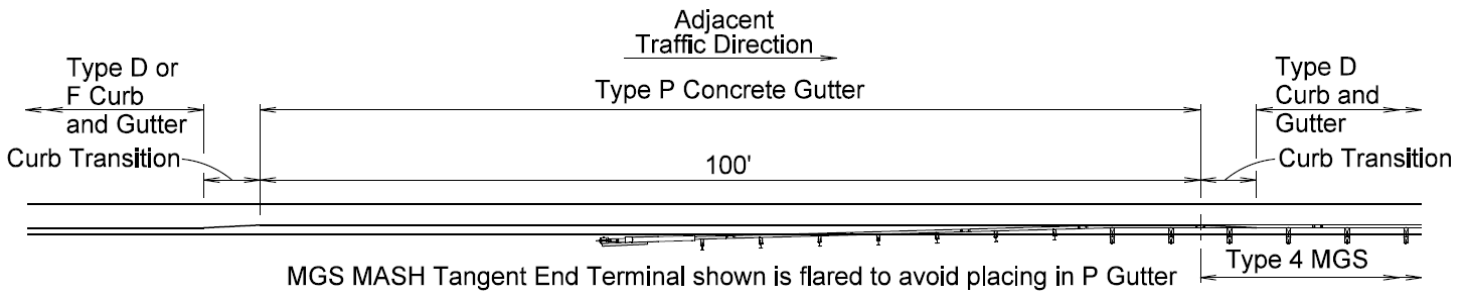


Figure 10-5 Guardrail adjacent to Curb and Gutter: Posted Speed Greater than 40 mph

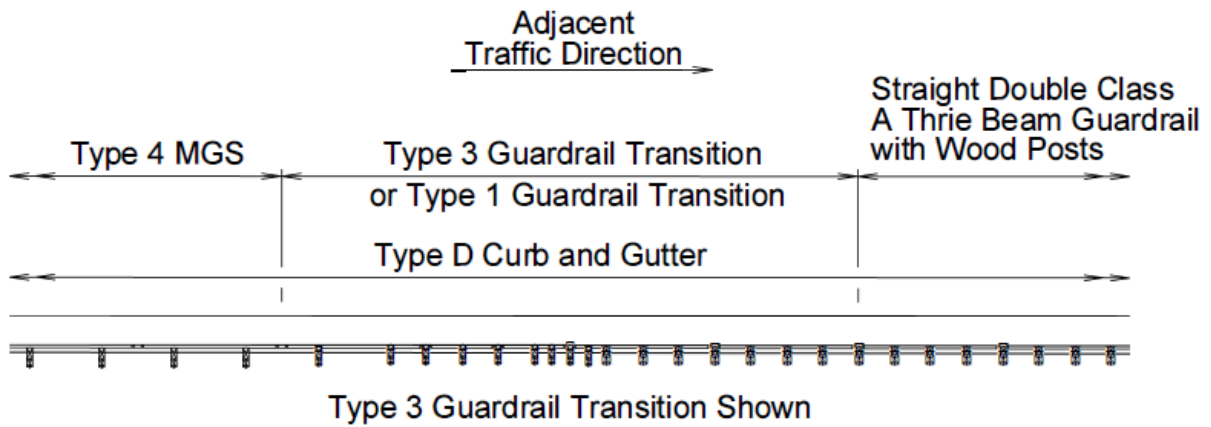


Figure 10-6 Type 4 MGS to Double (Nested) Thrie Beam Guardrail adjacent to Curb and Gutter: Posted Speed Greater than 40 mph

- Posted speed limit 40 mph or less

Cable guardrail is not allowed adjacent to any curbs except P Gutter.

Type 1 MGS can be used adjacent to all types of curb and gutter (Type B, D, F, and P gutter).

Only MGS MASH tangent end terminals will be used adjacent to all types of curb and gutter (Type B, D, F, and P gutter). See Figure 10-7.

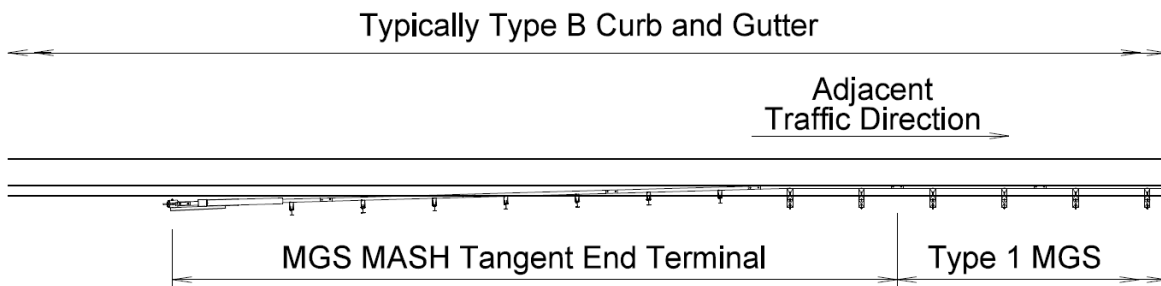


Figure 10-7 Guardrail adjacent to Curb and Gutter: Posted Speed 40 mph or less

DITCH BOTTOM

Ditch bottoms must be traversable when inside the clear zone. For more detail on ditch bottoms refer to Chapter 7 – Cross Sections. Refer to the current AASHTO publication of the *Roadside Design Guide*.

MEDIANS

If a median barrier is deemed necessary based on the guidance below, the least rigid median barrier should be considered first (cable, steel, and then concrete barrier). A typical median barrier SDDOT uses is a double-faced (back-to-back) 36-inch tall single slope reinforced concrete barrier. If necessary, taller single sloped barriers such as the 42-inch or 54-inch single slope barrier may be used. The 42-inch or 54-inch single slope barrier could be used when necessary based on higher truck traffic, need for headlight glare reduction, and need would be based on all project aspects. See section on CONCRETE BARRIERS.

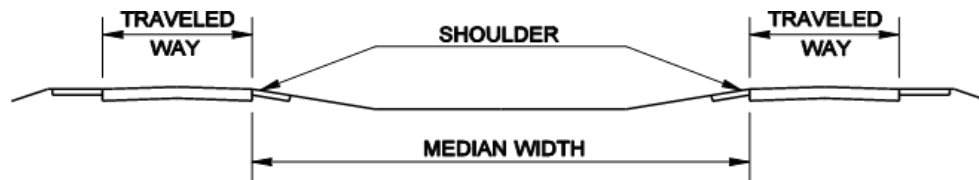
Non-Interstate Highways

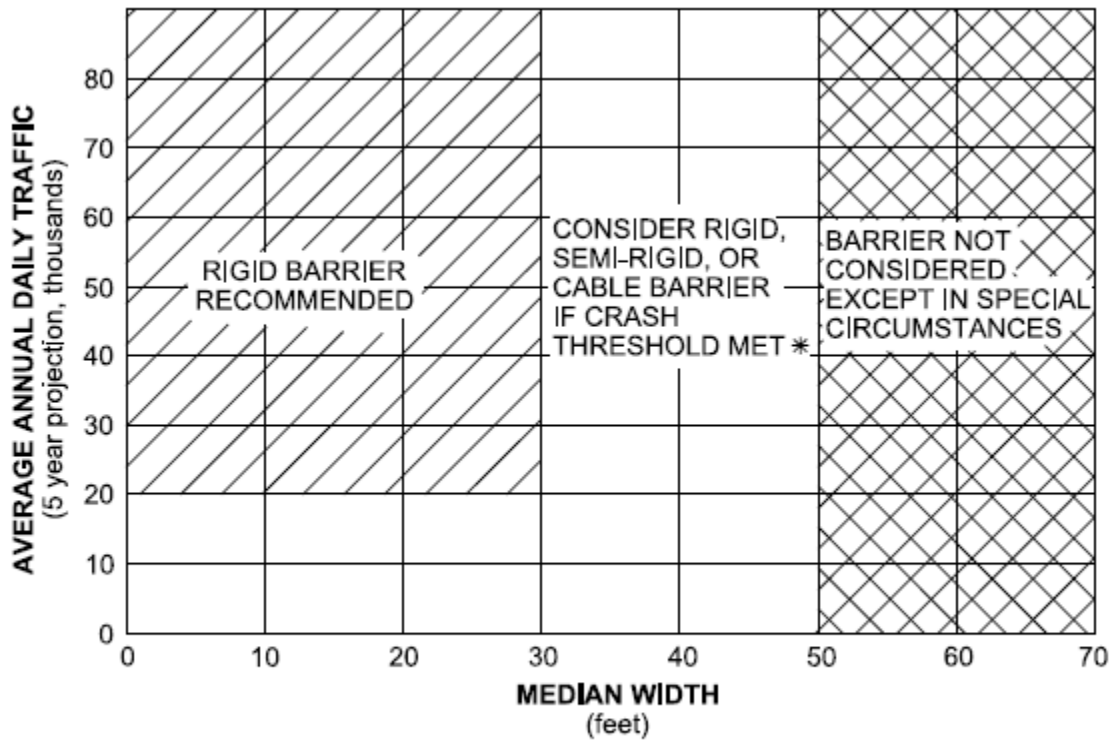
Studies have shown that median barriers can significantly reduce the occurrence of cross median crashes and the overall severity of median related crashes. With a great potential to reduce high severity crashes, rigid median barrier is recommended for high speed (\geq 55 mph Design Speed) non-interstate highways with a median width of less than 30 feet (measured from edge of traveled way to edge of traveled way) where the Design AADT is greater than 20,000 as shown in Figure 10-8.

To determine if a median barrier is necessary, a study should be performed which will include a cost/benefit analysis, crash review, and consultation with the Highway Safety Engineer for the following roadway characteristics:

- Median width less than 30 feet and the Design AADT is less than 20,000
- Median width is between 30 feet and 50 feet

At locations where median widths are greater than 50 feet a median barrier is not considered except in special circumstances such as a location with a significant history of cross median crashes. For a special circumstance, a cost/benefit analysis should be performed.





* Crash Threshold = An average of 0.5 or more Injury/fatal median crashes (overturning/sideswipe opposite/head-on) per mile in 5-year study period

Figure 10-8 Median Barrier Guidance for Non-Interstate highways

Interstate Highways

Studies have indicated the need for guidance on high speed interstate highways as conditions are changing throughout the state. With a great potential to reduce high severity crashes, rigid median barrier is recommended for high speed (≥ 55 mph Design Speed) interstate highways with a median width of less than 20 feet (measured from edge of traveled way to edge of traveled way) where the Design AADT is greater than 30,000 as shown in Figure 10-8A.

Median cable barrier is recommended at locations where the median width is between 30 feet and 50 feet and Design AADT is greater than 30,000.

To determine if a median barrier is necessary, a study should be performed which will include a cost/benefit analysis, crash review, and consultation with the Highway Safety Engineer for the following roadway characteristics:

- Median width less than 50 feet and the Design AADT is less than 30,000
- Median width is between 50 feet and 75 feet

At locations where median widths are greater than 75 feet a median barrier is not considered except in special circumstances such as a location with a significant history of cross median crashes. For a special circumstance, a cost/benefit analysis should be performed.

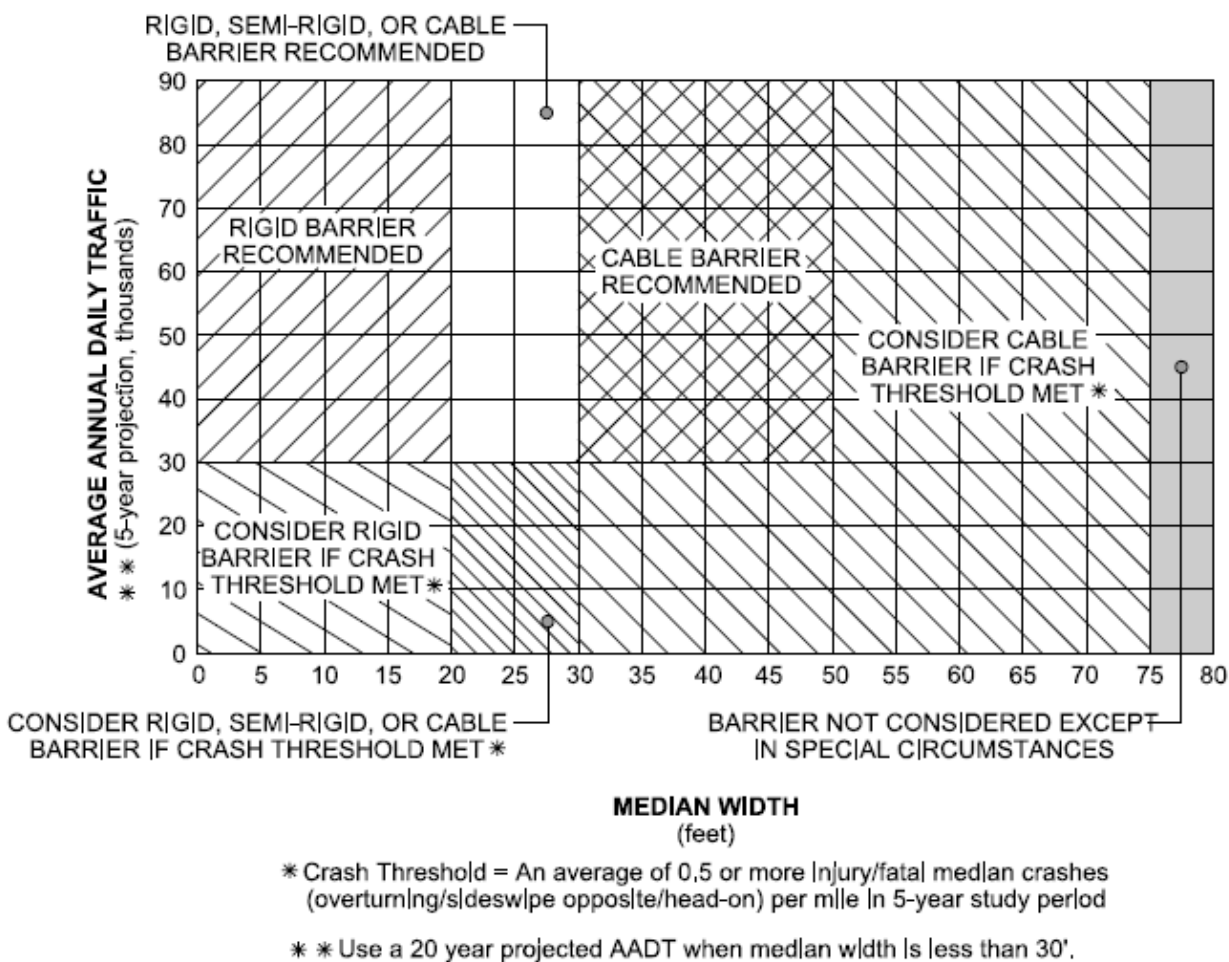


Figure 10-8A Median Barrier Guidance for Interstate highways

BARRIER TYPES

A barrier or guardrail is a device that provides a physical limitation to shield roadside obstacles or non-traversable terrain features. It is intended to contain or redirect an errant vehicle. Types of barrier used for permanent installations in South Dakota are:

- 36 inch (and taller) single slope reinforced concrete barrier and low profile concrete barrier (there may be instances where Jersey shape barriers are used on non-NHS routes)
- Steel beam guardrail (Thrie Beam, MGS, and W Beam)
- Cable barrier (South Dakota standard is High Tension Cable Guardrail)

Each type of barrier has different characteristics; however, all barriers must terminate with an approved crashworthy terminal. The crash test level of the terminals would typically be a TL-3 for 50 mph and greater speeds. A TL-2 crash tested terminal could be used for 45 mph or less speeds. SDDOT would typically use a MASH crash tested terminal. There will be instances where there are no MASH tested terminals or particular barrier system available and the designer would have to consider using an NCHRP 350 terminal or particular barrier system at a minimum.

SDDOT is moving toward using all MASH crash tested guardrail systems to align with the vehicles currently in use on the roads. See APPENDIX B for information regarding the differences between NCHRP 350 and MASH crash testing standards.

Upgrades to safety hardware will be considered on the following types of projects:

- Resurfacing (asphalt and concrete overlays, new asphalt surface, new concrete surface, resurfacing interstate shoulders, etc.)
- Reconstruction
- Bridge Deck Overlays
- Rehabilitation Projects (slope flattening, shoulder widening, etc.)

Types of project that upgrades may not be considered are as follows:

- Pavement Preservation
- General Roadway Maintenance (joint route and seal, etc.)

APPENDIX A provides detailed flowcharts to aid in determining whether or not to upgrade guardrail on a project when attached to a bridge. The designer should look at the existing condition of the barriers and end terminals (use HR54 Guardrail program and Guardrail Inspection and Maintenance Guidance) and verify that the condition is within the maintenance standards at a minimum. If there is a decision to not upgrade the barrier, then it will be noted in the designer's correspondence.

Barrier Characteristics

When barrier is necessary, the selection of a barrier should be based on the least rigid barrier type that offers the required degree of shielding at the overall lowest cost for the specific application. Refer to the current AASHTO publication of the *Roadside Design Guide* for further selection guidelines for use of a roadside barrier.

Table 10-10 provides information regarding the maximum deflection for the various types of barrier. The deflections shown provide guidance on what types of barrier can be used in certain situations. If there are roadside obstacles directly behind the barrier then you would select the type of barrier that would meet the requirements based on the distance available between the barrier and roadside obstacle. The deflections in the table are based on NCHRP 350 TL-3 crash testing, MASH TL-3 crash testing, measured deflections based on prior crashes, and the current AASHTO publication of the *Roadside Design Guide*.

It is recommended that the allowed deflection for steel beam guardrail design be measured from the obstacle to the back of the wood post when a post is located in front of the obstacle. Design deflection must be maintained a minimum of 25 feet at upstream of a rigid obstacle being shielded by semi-rigid barriers (steel beam guardrail) and if a trailing end terminal is used there must be 5 posts placed after the rigid obstacle. See Figure 10-9.

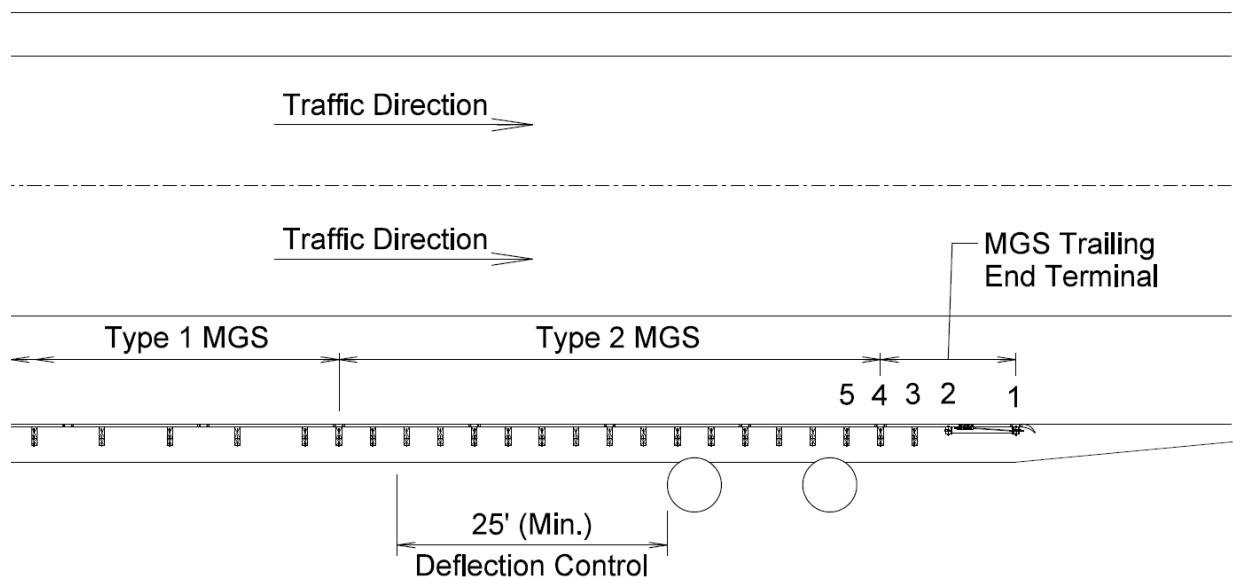


Figure 10-9 Design Deflection at Rigid Obstacles for Steel Beam Guardrail

Post spacing for low tension cable prior to obstacles should be as shown on the Standard Plate "3 Cable Guardrail Post Spacing for Deflection Control".

Post spacing for high tension cable guardrail prior to the obstacle will be determined by the Manufacturer or Developer of the system.

Table 10-10 Maximum Design Deflection of Barrier

Barrier Type		Post Spacing	Maximum Design Deflection
Rigid	Concrete Barrier	NA	0'
	Double(Nested) Thrie Beam Guardrail	3'-1 1/2"	0'-9"
Semi-Rigid	Thrie Beam Guardrail	3'-1 1/2"	1'-9"
		6'-3"	2'-6"
	Double (Nested) W Beam Guardrail	6'-3"	3'-0"
	MGS	1'-6 3/4"	3'-3"
		3'-1 1/2"	3'-9"
	6'-3"	5'-0"	
Flexible	Three Cable Guardrail	4'-0"	10'-6"
		8'-0"	11'-6"
		12'-0"	13'-0"
		16'-0"	15'-0"
	High Tension Cable Guardrail	Varies, Maximum Allowed is 16'	8'-0"

Table 10-11 provides height criteria for the various types of barrier.

Table 10-11 Height to Top of Barrier

Barrier Type	Standard Height	Allowable Height Variances for 3R Projects ¹	
Jersey Shape Concrete Barrier ²	32"	-3"	Variable ³
Single Slope Concrete Barrier	36"	-0" MASH TL-4 -4" MASH TL-3	Variable ³
Thrie Beam	32"	-2"	+2"
MGS ⁴	31"	-2" MASH TL-3	+2"
W Beam	28"	-1/4" NCHRP 350 TL-3	+1 1/2"
Three Cable	28"	-1/4" NCHRP 350 TL-3	+1 1/2"
High Tension Cable	Varies with Manufacturer	-1"	+1"

¹ The symbol "-" implies a lower elevation than standard height and "+" implies a higher elevation than standard height.

² The 32" Jersey Shape Concrete Barrier was typically used in South Dakota, but, conditions may warrant a different concrete barrier or a different height. See the current AASHTO publication of the *Roadside Design Guide* or other available research for more information regarding Concrete Barriers.

³ See the current AASHTO publication of the *Roadside Design Guide* or other available research for more information regarding Height Variance.

⁴ For typical MGS, different types may have different allowable height tolerance, check with the Standards Engineer.

Concrete Barriers

The single sloped (36" height) reinforced concrete barrier is the typical rigid barrier system used in South Dakota.

The 36" single slope concrete barrier meets the test level 4 crash test requirements of MASH. This barrier is used on structures where no deflection is allowed, at other locations where there is limited distance between the barrier and roadside obstacle, and at locations where deemed necessary due to high number of crashes with need to reduce maintenance costs of repairing other type of barriers.

The single sloped concrete barrier should not be installed on a slope steeper than a 10:1.

There is typically minor maintenance required after an impact with the single sloped reinforced concrete barrier.

Taller double-faced (also known as back-to-back faced) Jersey shaped safety barriers have been used in median locations with higher traffic counts and higher rates of cross median and in medians crashes. They were also installed with 2-foot high concrete glare screens. New back-to-back concrete barriers installed would be the 36-inch up to 54-inch height single slope reinforced concrete barrier. The height would be determined on a project-by-project basis depending on the safety needs at that location.

If concrete barriers are necessary, the Bridge Design Office should be notified in advance during the project scoping process. More on the topic of median barriers may be found in the current AASHTO publication of *Roadside Design Guide*, other available research, and the section on MEDIANS.

In urban areas or projects in the Black Hills where the design speed is less than 45 mph and there are sight distance concerns, there needs to be a more maintenance friendly barrier due to higher crash frequency. In these situations, a low-profile concrete barrier could be provided. It is recommended that the height of the barrier is 27". South Dakota does not have Standard Plates for this at this time, but the Office of Bridge Design has provided details and drawings for this barrier. If details are needed for these barriers, contact the Bridge Design Office.

Where aesthetics are a concern on context sensitive projects, the designer may consider the following barrier types:

- stone masonry wall barrier (only for posted speed of 40 mph or less)
- open concrete rail
- colored concrete barrier

It is recommended that rough textures, grooves (1/4" and deeper), and other shapes created on the traffic face of safety shaped concrete barriers not be used along high speed (\geq 55 mph Design Speed) facilities.

Concrete Barrier End Treatments

A Crash Cushion/Attenuator is an impact attenuator device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle or by redirecting the vehicle away from the hazard.

The approach end of concrete barrier will be transitioned to a non-gating Crash Cushion/Attenuator except when a longer length of need is necessary. If a longer length of need is necessary, then a transition to guardrail would be needed at the proper crash test level of MASH. A MASH test level 2 transition should be used for posted speeds of 40 mph and a MASH test level 3 transition should be used for posted speeds of 45 mph and greater. A tapered concrete barrier end treatment may be used if the posted speed is 35 mph and less.

The crash cushion/attenuator is typically anchored to a minimum of an 8-inch thick concrete pad; however, the Manufacturers of crash cushions have requirements for mounting the cushions to the pavement. The Manufacturer's installation requirements should be followed. The cross-slope of the pad should be level and the longitudinal grade will be the same throughout the crash cushion length at a minimum to enable proper connection to the concrete barrier and proper anchoring of the crash cushion. The crash cushion vertical alignment should match the vertical alignment of the concrete barrier. A transition from the concrete barrier to the crash cushion is typically needed.

The following provide further concrete end treatment barrier guidance for posted speeds:

- Posted speed limit 35 mph and less

The end treatment may be a tapered concrete end that transitions from the top of barrier to the curb. The vertical slope rate of the tapered end should be 8:1 or flatter. The tapered concrete end treatment does not meet MASH crash testing standards and would typically be used in locations with no history of barrier strikes. In a location that has a history of barrier strikes, the designer may elect to use a crash cushion that meets the test level 2 crash test requirements of MASH.

- Posted speed limit 40 mph

The crash cushion should not be placed on top of curbs higher than 4 inches. The 4-inch high curb will be in place for a minimum distance of 37.5 feet from the

beginning of the crash cushion and then the curb could be transitioned to a higher curb or no curb. The crash cushion should meet the test level 2 crash test requirements of MASH.

- Posted speed limit greater than 40 mph

The crash cushion may be placed adjacent to P gutter or no gutter. P gutter may be installed a minimum distance of 37.5 feet from the beginning of the crash cushion and then the P gutter could be transitioned to a curb or no curb. The crash cushion should meet the test level 3 crash test requirements of MASH.

Steel Beam Guardrail (Thrie Beam, MGS, and W Beam)

Thrie Beam Guardrail and MGS (Midwest Guardrail System) are standard semi-rigid barrier systems used in South Dakota. W Beam guardrail is not a current standard but may have to be used in rare circumstances or when a MASH crash tested version is not available.

Read the GENERAL NOTES on all the Standard Plates in the 630 series as these should help answer some questions you might have. The notes have statements regarding measurement and payment and typically refer to the appropriate bid item to use.

Steel beam guardrail usually remains functional after moderate to low speed impacts, thereby minimizing the need for immediate repair.

Steel beam guardrail should not be installed on a slope steeper than 10:1.

PI's (point where steel rail begins to flare) should typically be located at a post without a lap splice (See Standard Plates). The Standard Plates regarding transitions show where the guardrail can begin flaring.

Versions of steel beam guardrail may be used with curbs, see section for CURBS.

Single thrie beam guardrail that SDDOT uses has not passed MASH crash testing. SDDOT uses a modified blockout that should improve performance; however, it should be crash tested. Crash test proposals have been brought to the attention of the Midwest Pooled Fund, but the group has not approved funding.

It is assumed that double (nested) thrie beam as used in type 1, type 1 retrofit, and type 3 transitions would be acceptable to use as a stand alone barrier type since the transitions were approved as MASH TL-3 transitions.

The MGS comes in a variety of versions with various requirements. The versions of MGS as shown on SDDOT Standard Plates may be used. Not all versions of the MGS meet MASH crash testing standards but are being studied through NCHRP and various pooled fund studies. It is recommended that using a different version of MGS than what is shown on the Standard Plates must be reviewed by the Standards Engineer before it may be used.

On the NHS in the medians and outside shoulder where guardrail is attached to structures, SDDOT standard is to use a transition that meets the test level 3 crash test requirements of MASH (See section on BARRIER TRANSITIONS). These transitions attach from the concrete end block on the structure and transition to MGS. SDDOT should use MGS MASH Tangent End Terminals typically on the Interstate. See Design Example 1.

It is allowed to omit one post and blockout in a run of MGS. It is not allowed in any of the transitions. If the need to omit a post is close to an end terminal, close to a stiffness transition, installed at the breakpoint of a 2:1 slope, and adjacent to a curb, contact the Standards Engineer for a recommendation.

In situations when there is a need to span longer distances (e.g. over box culverts with shallow fill), the Longspan MGS can be used (see Standard Plate 630.27). If the span length is greater than 25 feet, contact the Standards Engineer and the Office of Bridge Design for special details.

Where aesthetics are a concern, the designer may elect to provide an AASHTO Type 4 rail (i.e. cortan/weathering steel); however, this type of rail would have a shorter useful life than the typical AASHTO Type 1 (galvanized) rail. End terminals would need to be stained to a "Natina" finish to match the weathering steel color as suppliers will not supply end terminals constructed of weathering steel.

Thrie Beam Guardrail End Terminals

The approach end of thrie beam guardrail will typically be transitioned to the MGS before termination.

The departure end of thrie beam guardrail may be terminated with a trailing end terminal only if the terminal cannot be struck by oncoming traffic, such as on divided roadways where traffic only travels in one direction.

MGS MASH End Terminals

MGS MASH end terminals are the standard end terminals used for MGS. When designing MGS, the effective length varies depending on the type of end terminal used. The designer will specify in the plans which end terminal (Flared or Tangent) will be constructed. See the approved products list for these types of end terminals (MGS MASH Tangent End Terminal or MGS MASH Flared End Terminal). There is not as large of a length reduction advantage with the new MASH flared end terminal as there was in the past for a flared end terminal. There is typically a savings of none, one, or maybe two sections of rail compared to the tangent end. See Figure 10-10 and Figure 10-11.

The MGS MASH Tangent End Terminals from the approved products list have the option of being installed at a 25:1 flare rate. It is recommended to install the tangent end terminals at the 25:1 flare rate for the following situations:

- when the front face of rail at the end terminal will be within 7 feet of the edge of traveled way and there is ample space available to flare the end terminal
- to help achieve the strongly recommended 4.5 feet minimum distance between the front face of the rail at the end terminal and the edge of traveled way.

It will depend on the site condition and the discretion of the designer whether the 25:1 flare rate is used on the installation of the tangent end terminal.

Pay special attention to Standard Plates 630.87, 630.89, and 630.90 when drawing/designing MGS regarding embankment limits and pay limits. The embankment and inslopes should be used as shown on these Standard Plates.

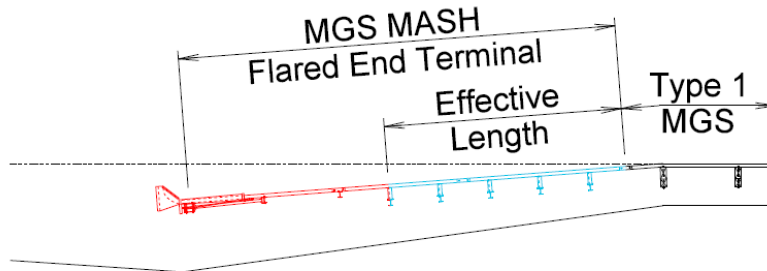
If there is a location where guardrail is attached to a structure and only minimum length is needed, the embankment slopes for the end terminal must be adhered to. If the slopes are not obtainable, extend the guardrail to a place where the embankment can be constructed in accordance with Standard Plates 630.87, 630.89, or 630.90.

Only MGS MASH Tangent End Terminals should be installed adjacent to areas with curb and gutter. See the section regarding CURBS.

At the departure end of MGS on divided highways, where traffic only travels in one direction and does not approach the guardrail, MGS Trailing End Terminals are used. The MGS trailing end terminal should never be used where oncoming traffic could strike the end of the terminal.

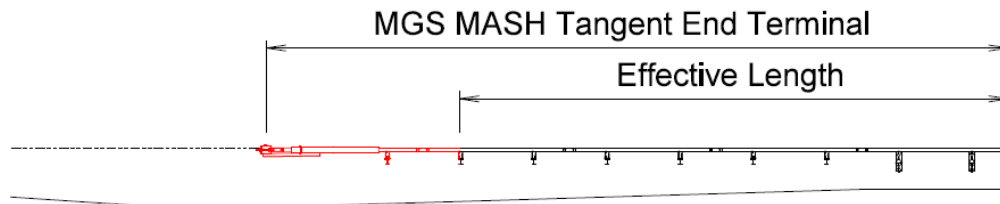
There is an approved products list for MGS Flared End Terminals and MGS Tangent End Terminals. These are the former NCHRP 350 crashworthy end treatments and are used only for replacement of existing end terminals due to a crash such as with maintenance

contracts. These end terminals do not meet current MASH crash testing requirements and should not be used in new designs.



Use the cell "MGS MASH Flared End Terminal with Embankment" from the "SteelBeamGuardrail" cell library for design purposes.

Figure 10-10 MGS MASH Flared End Terminal



Use the cell "MGS MASH Tangent End Terminal with Embankment" from the "SteelBeamGuardrail" cell library for design purposes.

Figure 10-11 MGS MASH Tangent End Terminal

W Beam Guardrail End Terminals

W Beam guardrail end terminals are not the standard; however, they may be used when replacing end terminals damaged by crashes as a replacement or in special circumstances. If a long length of W Beam guardrail is used, the W Beam must transition to MGS and terminate with an MGS MASH end terminal. Shorter lengths of W Beam guardrail, such as minimum length guardrail, would terminate with a W Beam Guardrail Flared End Terminal or a W Beam Guardrail Tangent End Terminal (see the approved products list for these types of end terminals). The designer will specify in the plans which end terminal (Flared or Tangent) will be constructed.

W Beam Guardrail Flared End Terminals (Figure 10-12) should assume 25 feet of the guardrail is available as part of the effective length of rail when designing guardrail.

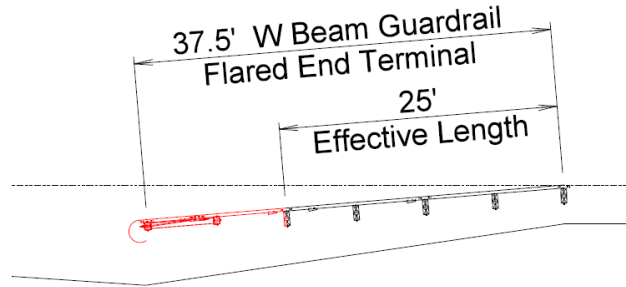


Figure 10-12 W Beam Guardrail Flared End Terminal

W Beam Guardrail Tangent End Terminals (Figure 10-13) should assume 37.5 feet of the guardrail (tangent to the roadway) is available as part of the effective length of rail when designing guardrail.

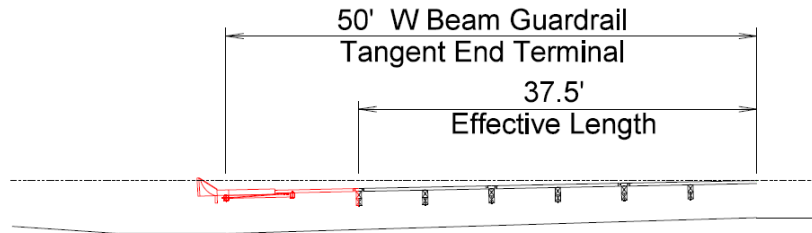


Figure 10-13 W Beam Guardrail Tangent End Terminal

At installations of non-flared (tangent) guardrail where the fill height is greater than 10 feet, consider using the W Beam Guardrail Tangent End Terminal unless it is more cost effective to use a W Beam Guardrail Flared End Terminal based on crash history and cost.

Three Cable Guardrail (Low Tension)

Three Cable Guardrail (low tension) is no longer the standard flexible barrier system used in South Dakota. South Dakota's preference is to use high tension cable guardrail.

Primary advantages that cable guardrail has over the other types of barrier installations is that its open design reduces snow drifting problems and reduces the potential for injury when hit.

Although the cable guardrail is relatively inexpensive to install and performs well when hit, it must be repaired after each hit to maintain its effectiveness. Its use in areas where it is likely to be hit frequently, such as on the outside of sharp curves, is not recommended. Cable guardrail also has reduced effectiveness on the inside of curves. Refer to the 3 Cable Guardrail Standard Plate 629.01 for post spacing on horizontal curves.

Cable guardrail must be installed and maintained as close to the design height as feasible to function properly.

Cable guardrail will not be placed on slopes steeper than 10:1, will not be installed where the approach slope is steeper than 10:1, and will not be placed adjacent to a curb or in combination with a curb.

Protecting slopes 3:1 and steeper require a special design when using 3 cable guardrail (low tension). The special design consists of a post spacing of 4 feet and a berm (platform) at least 4 feet wide behind the cable guardrail. The berm slope will match the roadway cross slope or be no steeper than 10:1. The posts will only be the S3x5.7 steel posts with soil plates. This should be stated on the plans by the designer.

Two other options may be used when there are steep slopes. One option is to use Type 1C MGS at the breakpoint of the slope. This could cause more snow drifting issues than the cable guardrail, but it would have less deflection and would be easier to maintain. See the prior section regarding Steel Beam Guardrail. Another preferred option is to place a high tension cable guardrail with 2 feet of embankment. Refer to the next section regarding High Tension Cable Guardrail.

Three Cable Guardrail (Low Tension) End Terminals

There are two types of three cable guardrail end terminals. The Three Cable Guardrail Anchor Assembly and the Slip Base Three Cable Guardrail Anchor Assembly.

The Three Cable Guardrail Anchor Assembly (Figure 10-14) is used only behind the W Beam Guardrail in the W Beam to 3 Cable Guardrail Transition and behind interlaced cable when cable lengths are longer than 1000 feet (see Standard Plate 629.01).

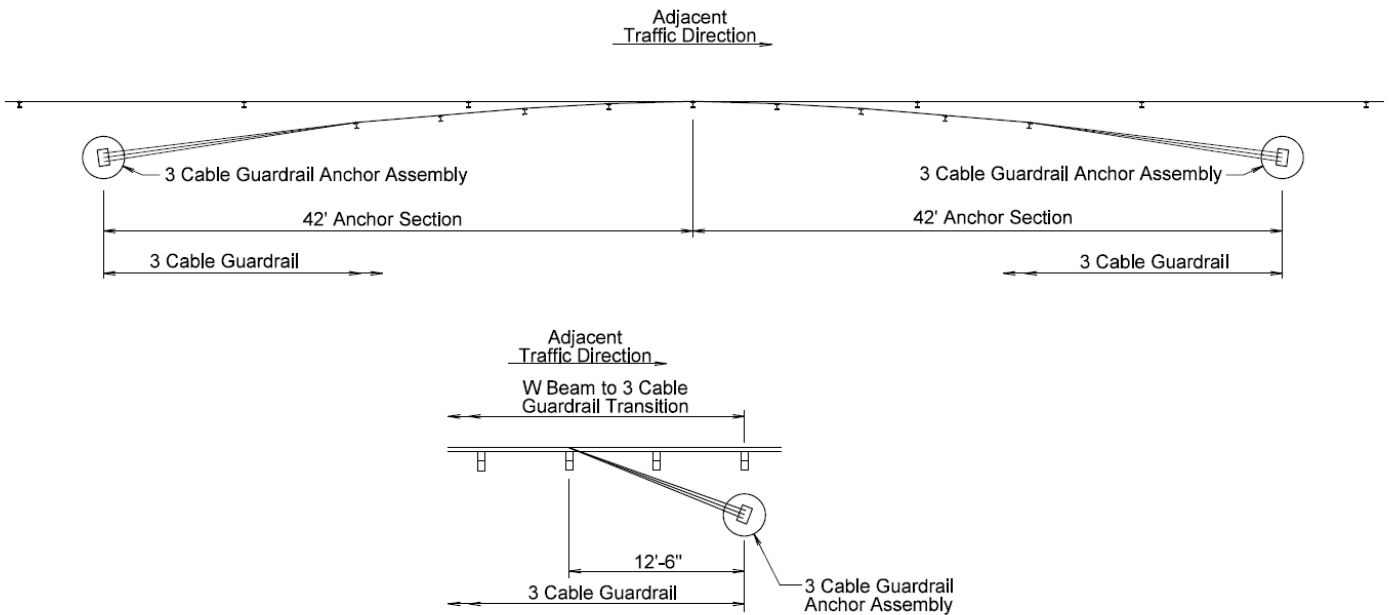


Figure 10-14 Three Cable Guardrail Anchor Assembly

The Slip Base Three Cable Guardrail Anchor Assembly (Figure 10-15) is the standard end treatment for three cable guardrail. Forty feet from the first vertical post of this terminal is considered non-effective for determining the length of the guardrail system needed.

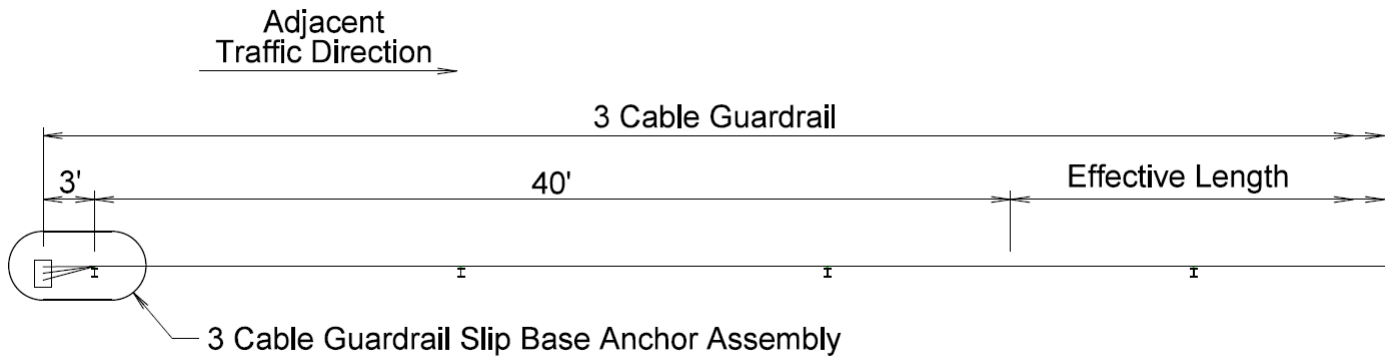


Figure 10-15 Slip Base Three Cable Guardrail Anchor Assembly

High Tension Cable Guardrail

The term “High Tension Cable Guardrail” has the same meaning as the term “High Tension Cable Barrier” as it is used in SD. The plan notes and bid items use the term “High Tension Cable Guardrail” while industry typically uses the term “High Tension Cable Barrier”.

A primary advantage high tension cable guardrail has over the other types of barrier installations is that its open design, similar to the 3 cable guardrail (low tension), reduces snow drifting problems on or alongside the roadway as compared to steel beam guardrail.

Although high tension cable guardrail performs well when hit, it must be repaired after each hit to maintain its original effectiveness. High tension cable guardrail should be able to retain tension in the cables adequately after a crash, depending on the nature of the crash, and may offer limited protection until it is repaired. Crashes at the end anchor assemblies would typically release the cables and would require repair.

High tension cable guardrail may be used as a stand-alone cable barrier when the need arises such as protecting steep slopes when there is not enough room for extra embankment or when the deflection requirements would require using high tension cable guardrail instead of 3 cable guardrail (low tension).

To protect a steep slope with high tension cable guardrail there would need to be a 2-foot embankment behind the high tension cable guardrail and the cross slope of the berm will match the roadway cross slope or be no steeper than 10:1.

Bridge columns or other obstacles on Interstates should be protected with high tension cable guardrail if the cable barrier is stand-alone (not attached and transitioned into W beam) and the obstacle is 8 feet or more from the high tension cable guardrail. It is preferred to keep cable barriers a minimum of 15' from median columns on divided highways to allow for maintenance equipment to access behind the cable barrier and allow for deflections such as only one cable engaging a vehicle during a crash.

See Section B – Grading Notes for plan notes regarding high tension cable guardrail. The notes contain information regarding design and plan information. Also, see the DESIGN EXAMPLES.

High Tension Cable Guardrail Anchor Assembly

For design purposes, SDDOT uses 26' of the anchor assembly as the approach non-effective length and 51' of the anchor assembly as the departure non-effective length in high tension cable guardrail designs. Plans will dimension the non-effective portion of the anchorages in the guardrail layout as well as the overall length of the high tension cable guardrail. Plans will also show and label the payment limits of the high tension cable guardrail anchor assembly. Prior to construction at the preconstruction meeting the Contractor needs to know which high tension cable guardrail is being installed so the Design Engineer can adjust the guardrail embankment limits and cable lengths for the Project Inspector. Changes to the high tension cable guardrail notes from Section B – Grading Notes must be approved by the Standards Engineer.

Standard Microstation cells for high tension cable guardrail and the anchorages have not been made available yet. If they have been placed on the Downloadable Files SDDOT web page disregard this paragraph.

See Figure 10-16 for an example showing a picture and a drawing of one of the high tension cable guardrail anchor assemblies SDDOT uses. Section B - Grading Notes contain more information about the anchor assemblies provided in designs.



Adjacent
Traffic Direction →

Effective Length

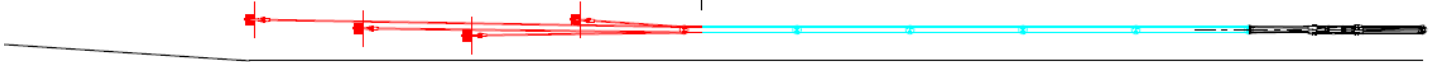


Figure 10-16 Example High Tension Cable Guardrail Anchor Assembly

BARRIER TRANSITIONS

Various types of transitions are used based on the type of barrier installed. Typically the transitions are deflection (stiffness) transitions. Transition sections are necessary to provide continuity of protection when two different barriers are joined together (i.e. flexible to semi-rigid barrier or from a semi-rigid to rigid barrier) or within the same type of barrier (typically steel beam guardrail) with different design deflections. If a steel beam guardrail contains two different design deflections adjacent to each other, then the steel beam guardrail transitional length should be approximately 10 times the difference in design deflection distance. The most common transition occurs between the approach guardrail attached to bridge rail ends also known as end blocks.

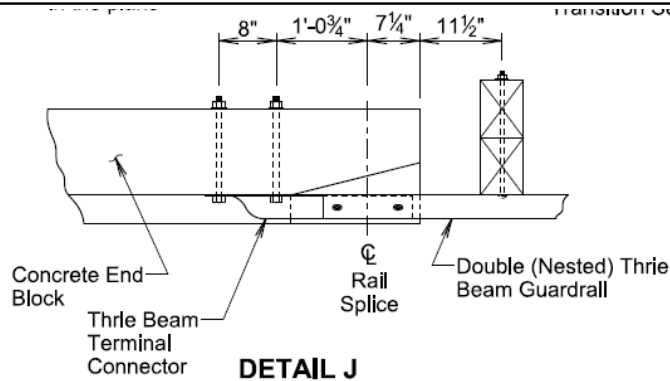
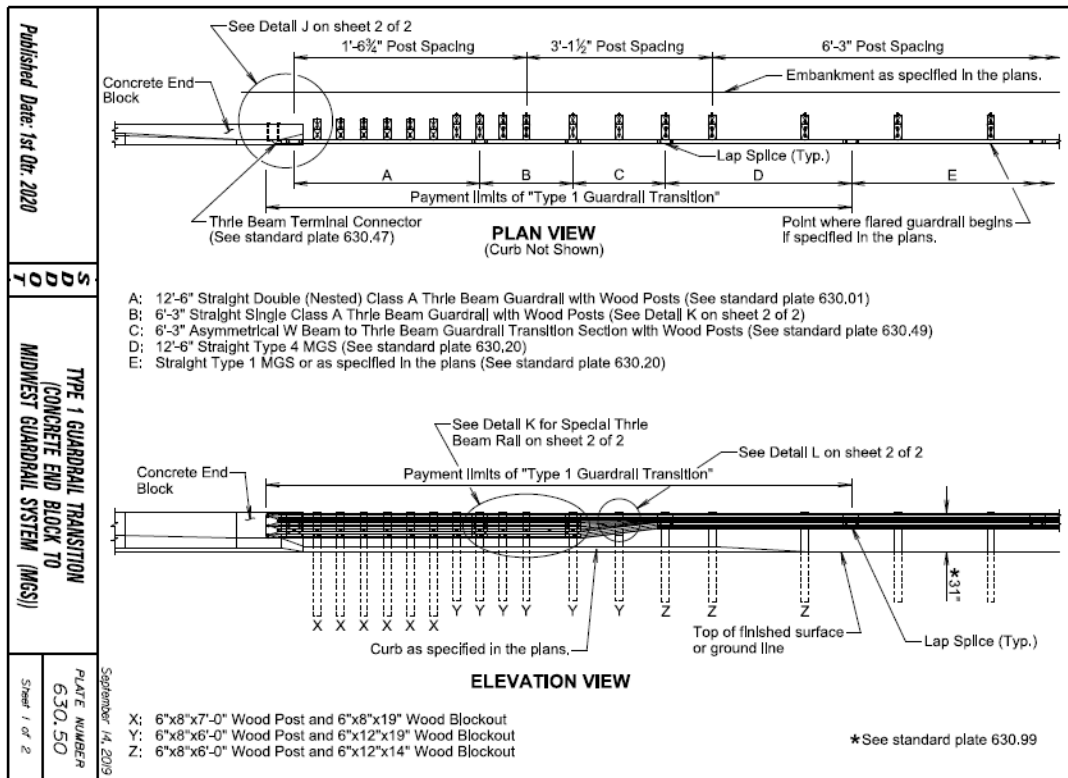
The types of transitions used in South Dakota are shown on the Standard Plates which include payment limits that must be shown in the guardrail designs in the plans.

Below is a list of the guardrail transitions and additional information regarding the transitions (See APPENDIX A):

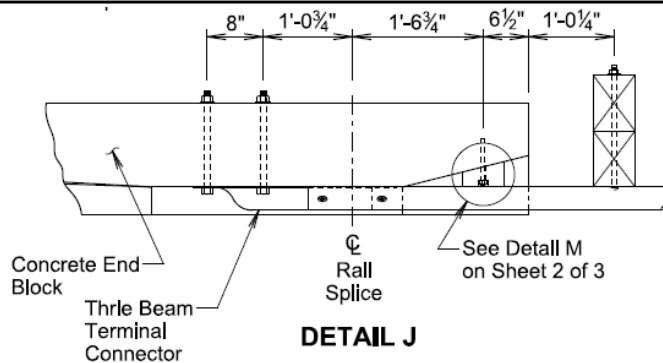
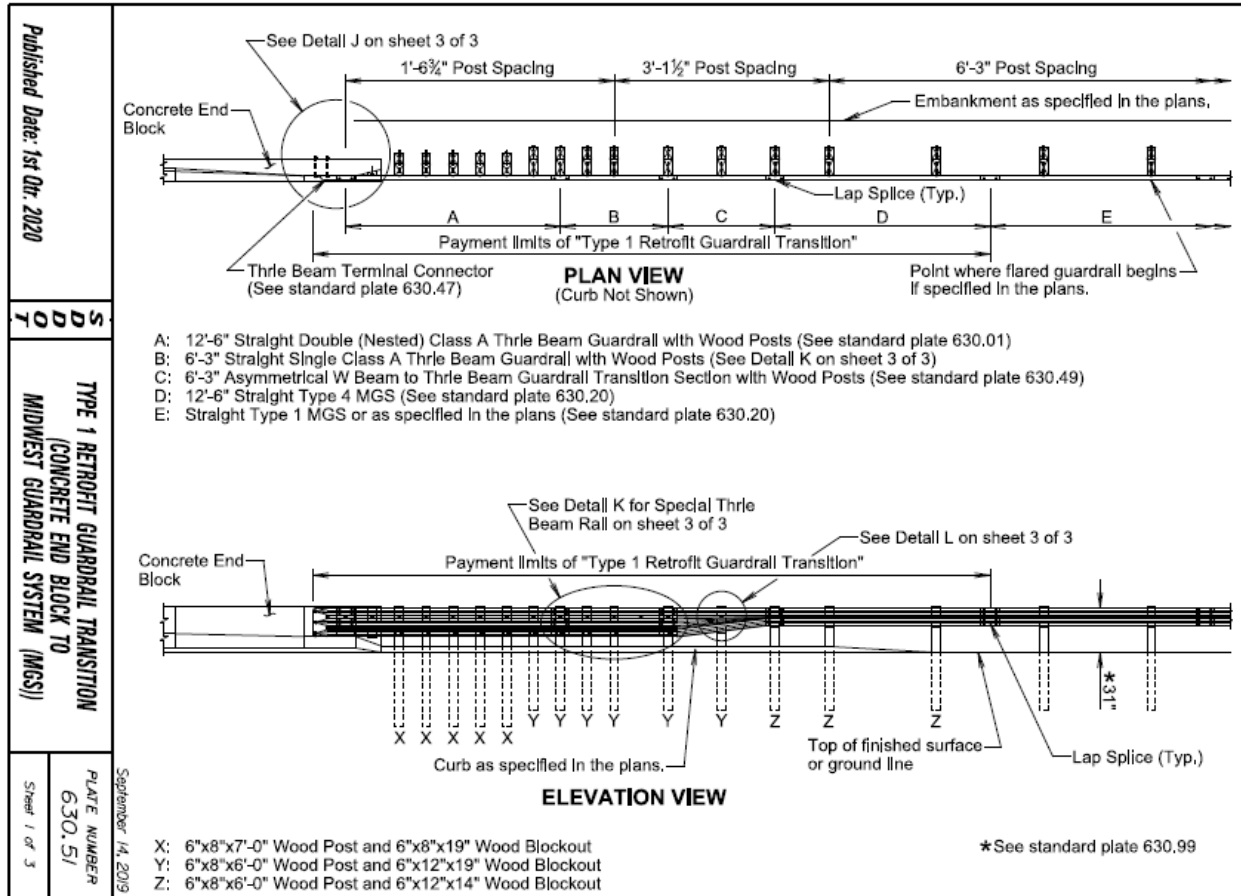
* Considered as meeting NCHRP 350 TL-3

** Considered as meeting MASH TL-3

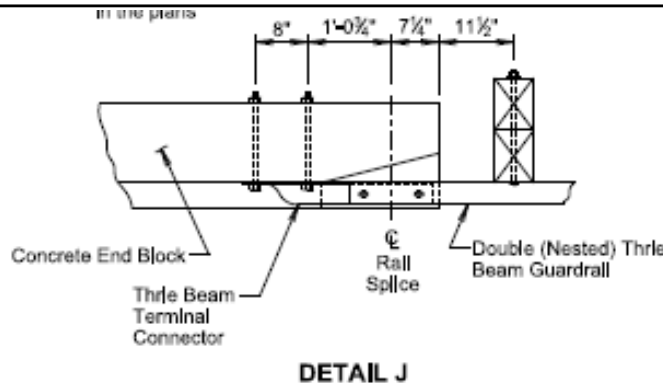
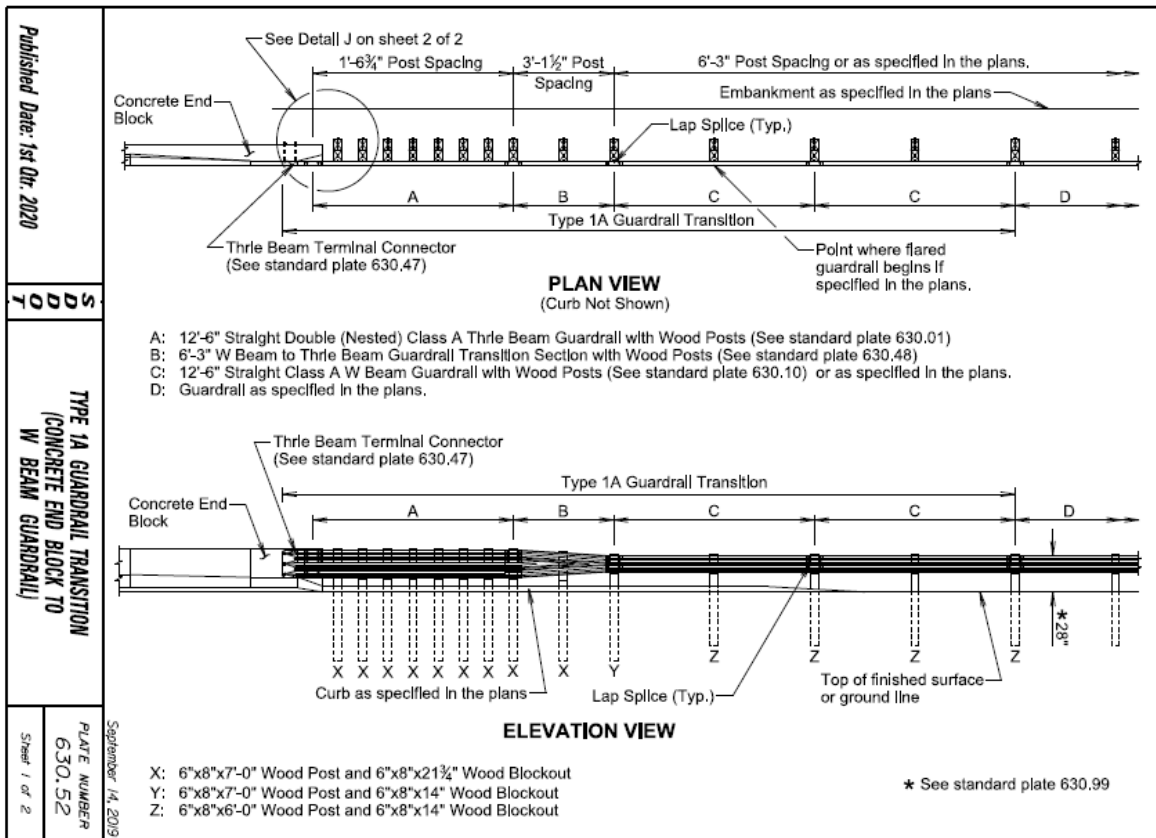
- ** Type 1 Guardrail Transition (Concrete End Block to MGS): This transition is typically used when attaching the guardrail to a relatively new structure. See Detail J as it shows the dimensions of where the Terminal Connector is attached, it must match what is shown in the structure portion of the original or new plans.



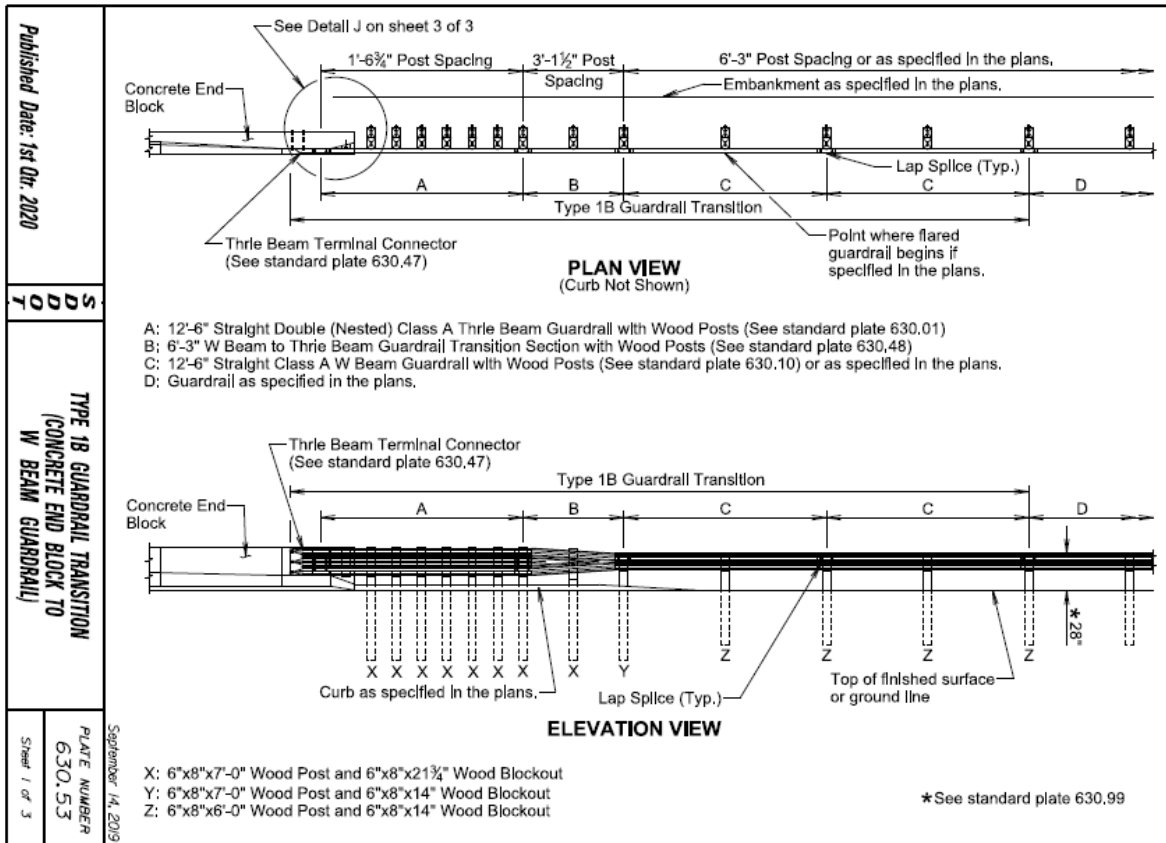
- ** Type 1 Retrofit Guardrail Transition (Concrete End Block to MGS): This transition is typically used when attaching the guardrail to a structure that was built approximately 25 years ago and less. See Detail J as it shows the dimensions of where the Terminal Connector is attached, it must match what is shown in the structure portion of the original construction plans or what was constructed.



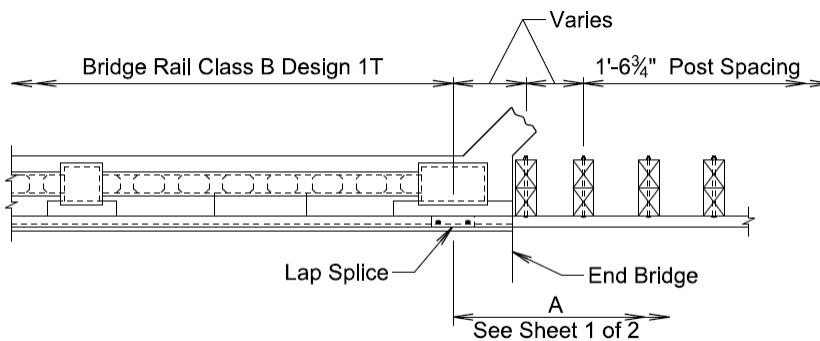
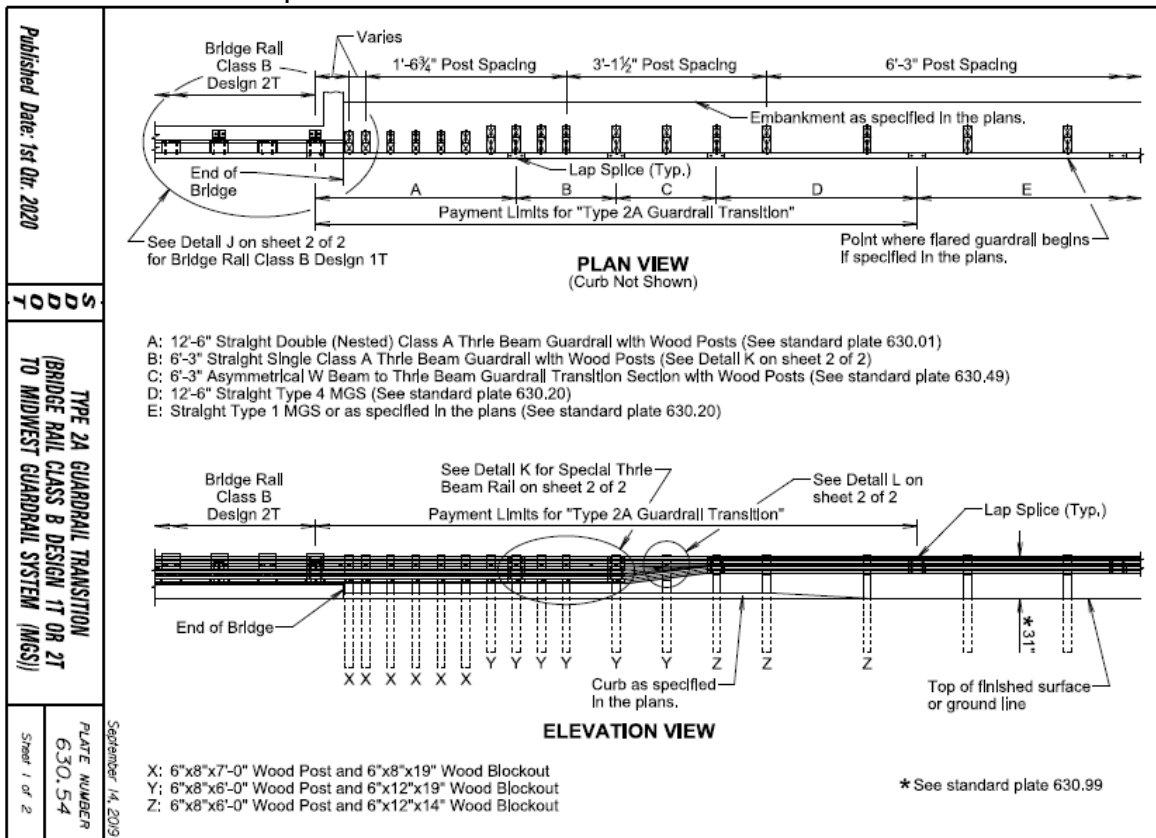
- * Type 1A Guardrail Transition (Concrete End Block to W Beam Guardrail): This transition is typically used when attaching the guardrail to a relatively new structure. This transition would only be used when the W Beam would transition to 3 cable (low tension) guardrail. SDDOT preference is to use the Type 1 transition instead and use MGS until it terminates with MGS MASH Tangent or Flared End Terminal. See Detail J as it shows the dimensions of where the Terminal Connector is attached, it must match what is shown in the structure portion of the original or new plans.



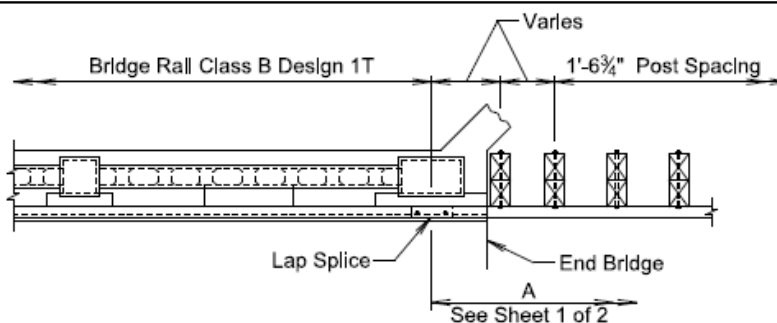
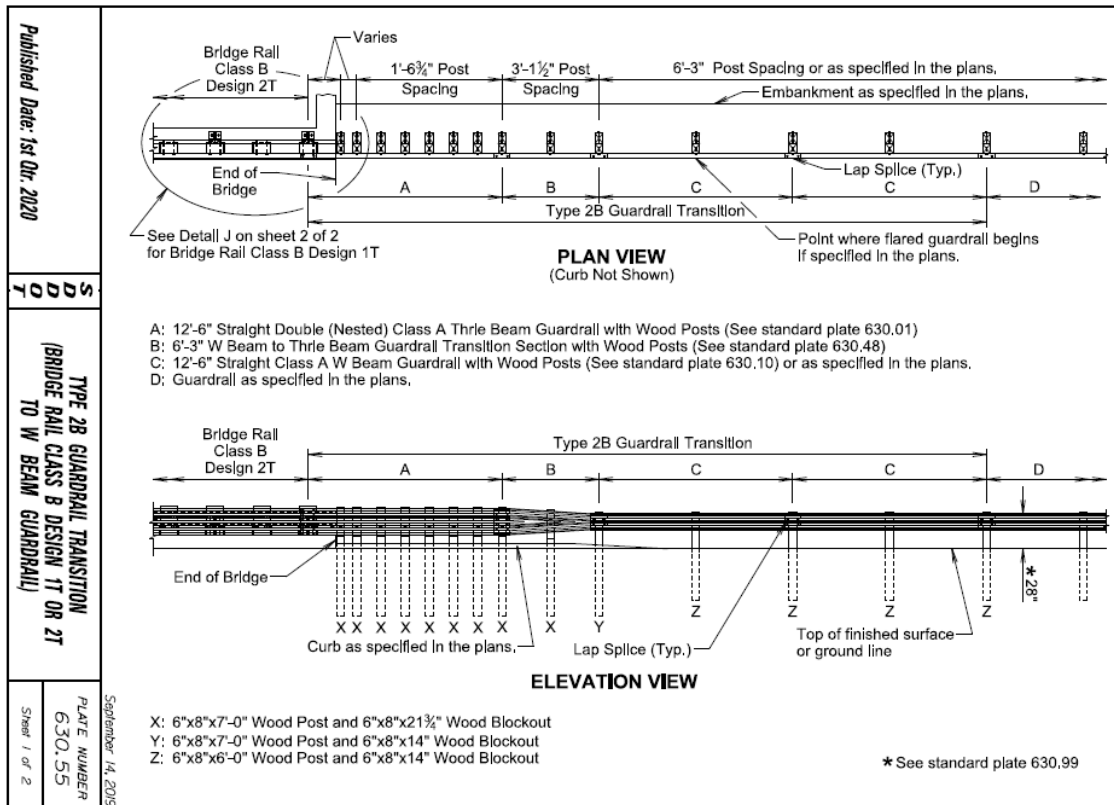
- * Type 1B Guardrail Transition (Concrete End Block to W Beam Guardrail): This transition is typically used when attaching the guardrail to a structure that was built approximately 25 years ago and less. This transition would only be used when the W Beam would transition to 3 cable (low tension) guardrail. SDDOT preference is to use the Type 1 retrofit transition instead and use MGS until it terminates with MGS MASH Tangent or Flared End Terminal. See Detail J as it shows the dimensions of where the Terminal Connector is attached, it must match what is shown in the structure portion of the original or new plans.



- * Type 2A Guardrail Transition (Bridge Rail Class B Design 1T or 2T to MGS): This transition is typically used when attaching the guardrail to a structure that was built more than 25 years ago. See Detail J as it shows the bridge rail class B design 1T. If the bridge rails of these types need to remain based on the flowcharts in APPENDIX A and scoping discussions, it would be the preference as the rail transitions to MGS. This transition was considered an NCHRP 350 TL-3 transition because the bridge rail to double (nested) thrie beam transition was not crash tested to MASH TL-3 requirements.

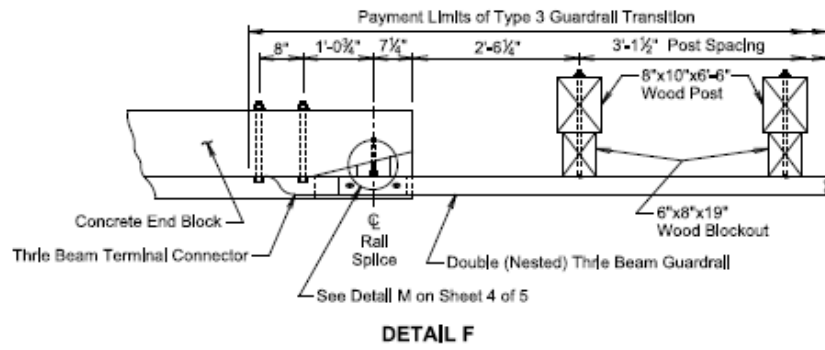
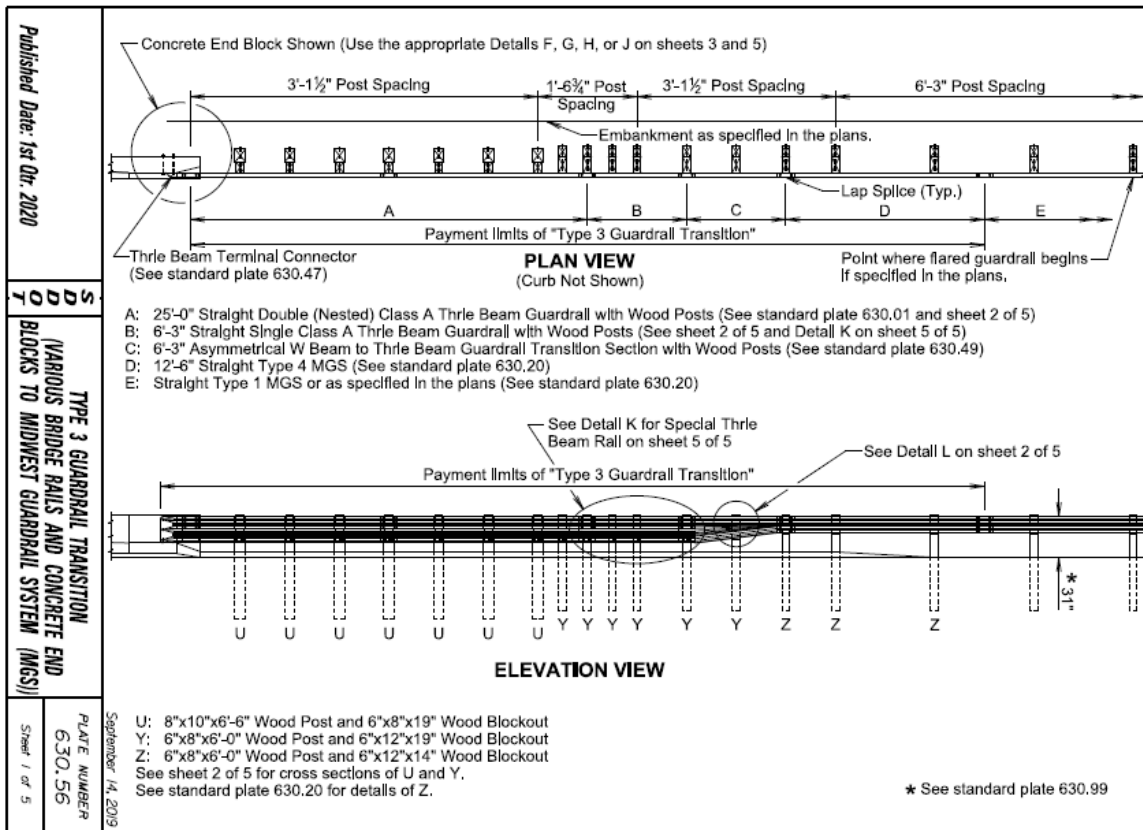


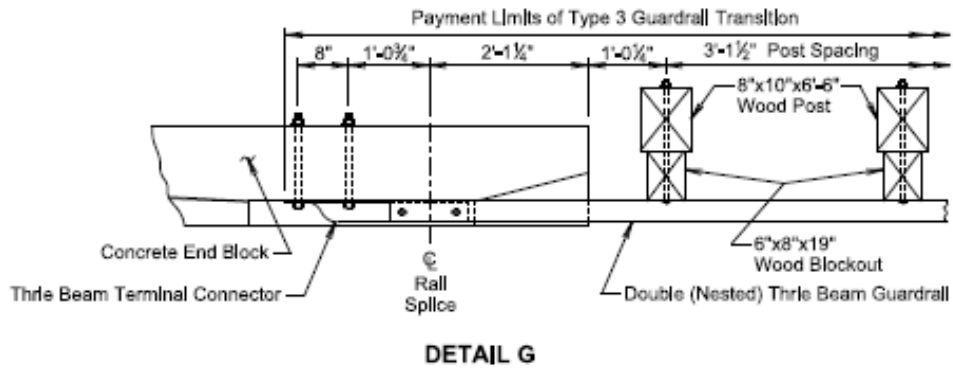
- * Type 2B Guardrail Transition (Bridge Rail Class B Design 1T or 2T to W Beam Guardrail): This transition is typically used when attaching the guardrail to a structure that was built more than 25 years ago. See Detail J as it shows the bridge rail class B design 1T. If the bridge rails of these types need to remain based on the flowcharts in APPENDIX A and scoping discussions, then this transition would only be used if the W beam guardrail would transition into 3 cable (low tension) because there is a long length of barrier need. SDDOT preference would be using the Type 2A Guardrail Transition instead of this transition as the Type 2A rail transitions to MGS.



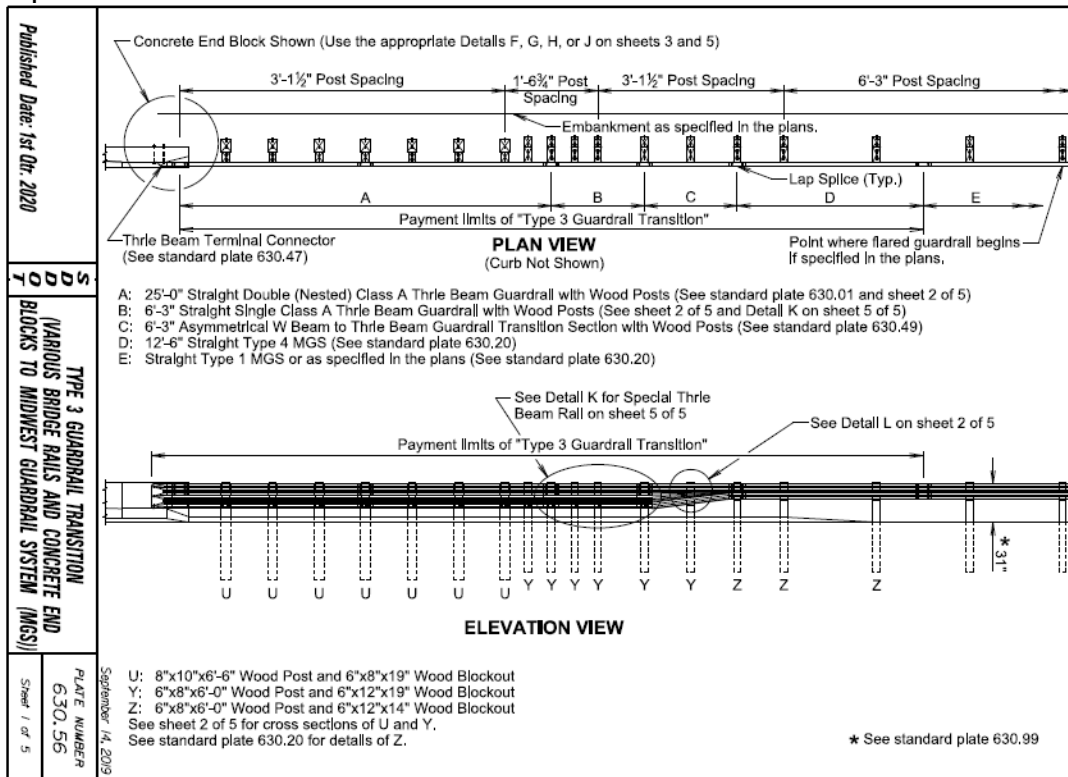
DETAIL J

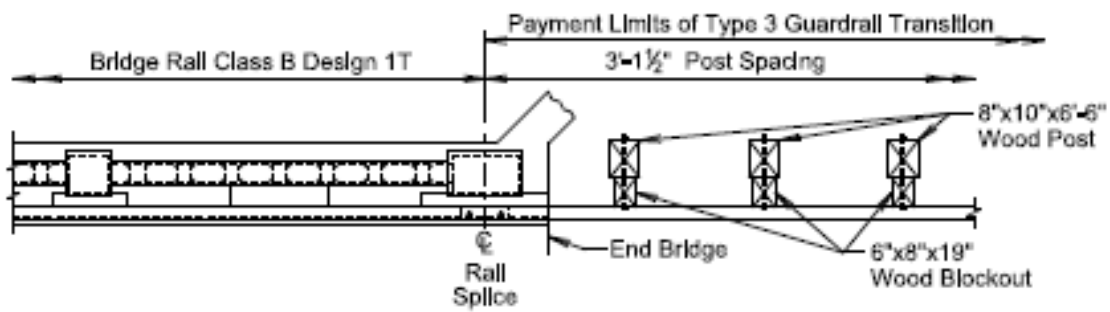
- ** Type 3 Guardrail Transition (Concrete End Block to MGS): This transition was added as an option to aid cases where the cross pipe of a drop inlet interferes with a guardrail post. The transition consists of a double (nested) thrie beam that transitions to MGS. The posts in the double (nested) thrie beam portion are spaced wider to accommodate more chances of missing an in place drop inlet cross pipe. If you are using minimum length guardrail in your design and this plate, the total guardrail length would be longer by 12'-6" due to the extra length of the transition.



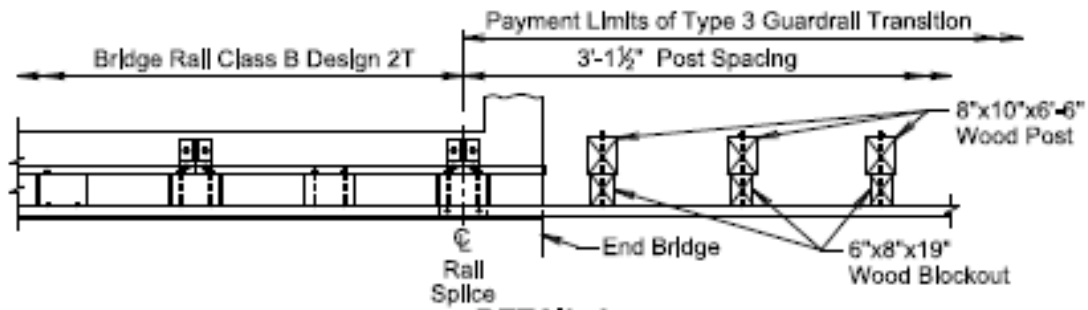


- * Type 3 Guardrail Transition (Bridge Rail Design 1T or 2T to MGS): This transition was added as an option to aid cases where the cross pipe of a drop inlet interferes with a guardrail post. The transition consists of a double (nested) thrie beam that transitions to MGS. The posts in the double (nested) thrie beam portion are spaced wider to accommodate more chances of missing an in place drop inlet cross pipe. If you are using minimum length guardrail in your design and this plate, the total guardrail length would be longer by 12'-6" due to the extra length of the transition. This transition was considered an NCHRP 350 TL-3 transition because the bridge rail to double (nested) thrie beam transition was not crash tested to MASH TL-3 requirements.



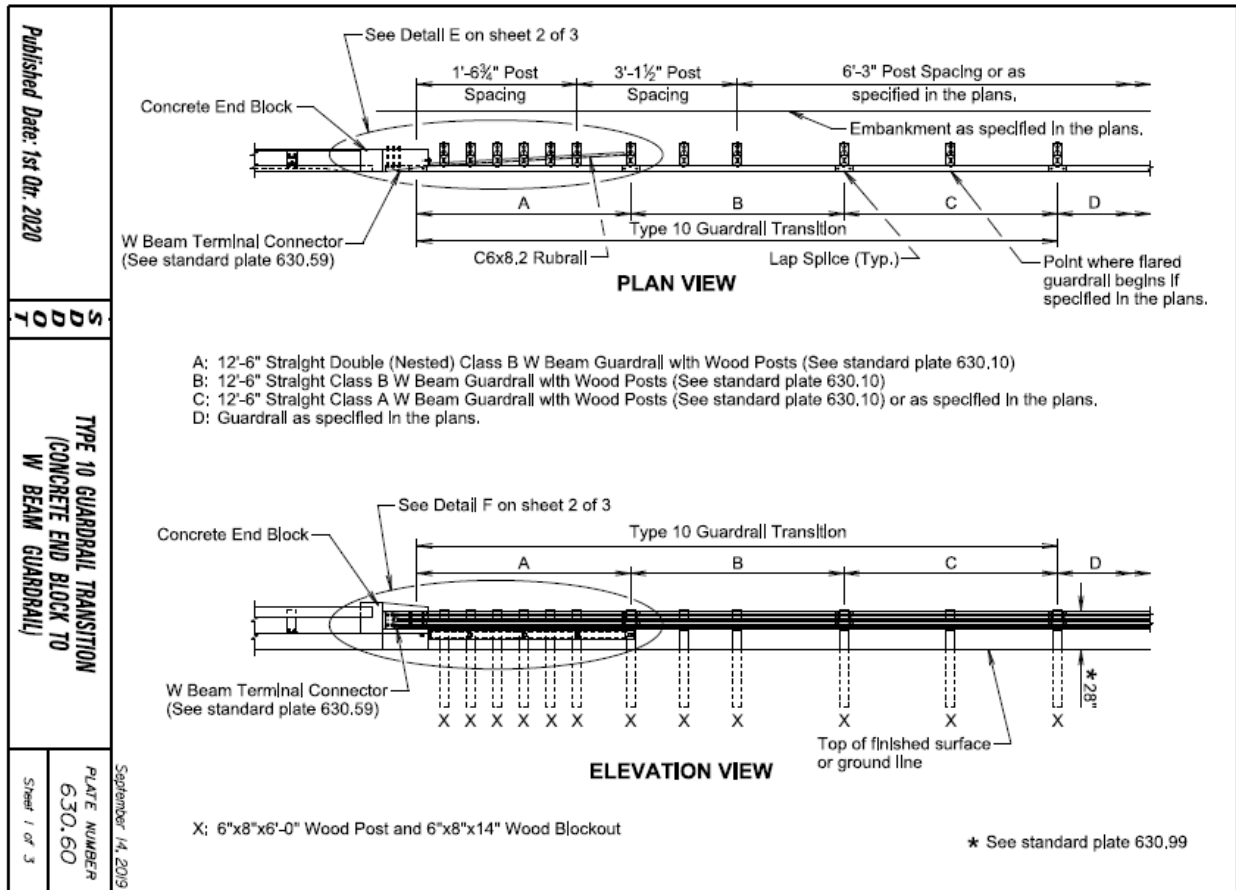


DETAIL H

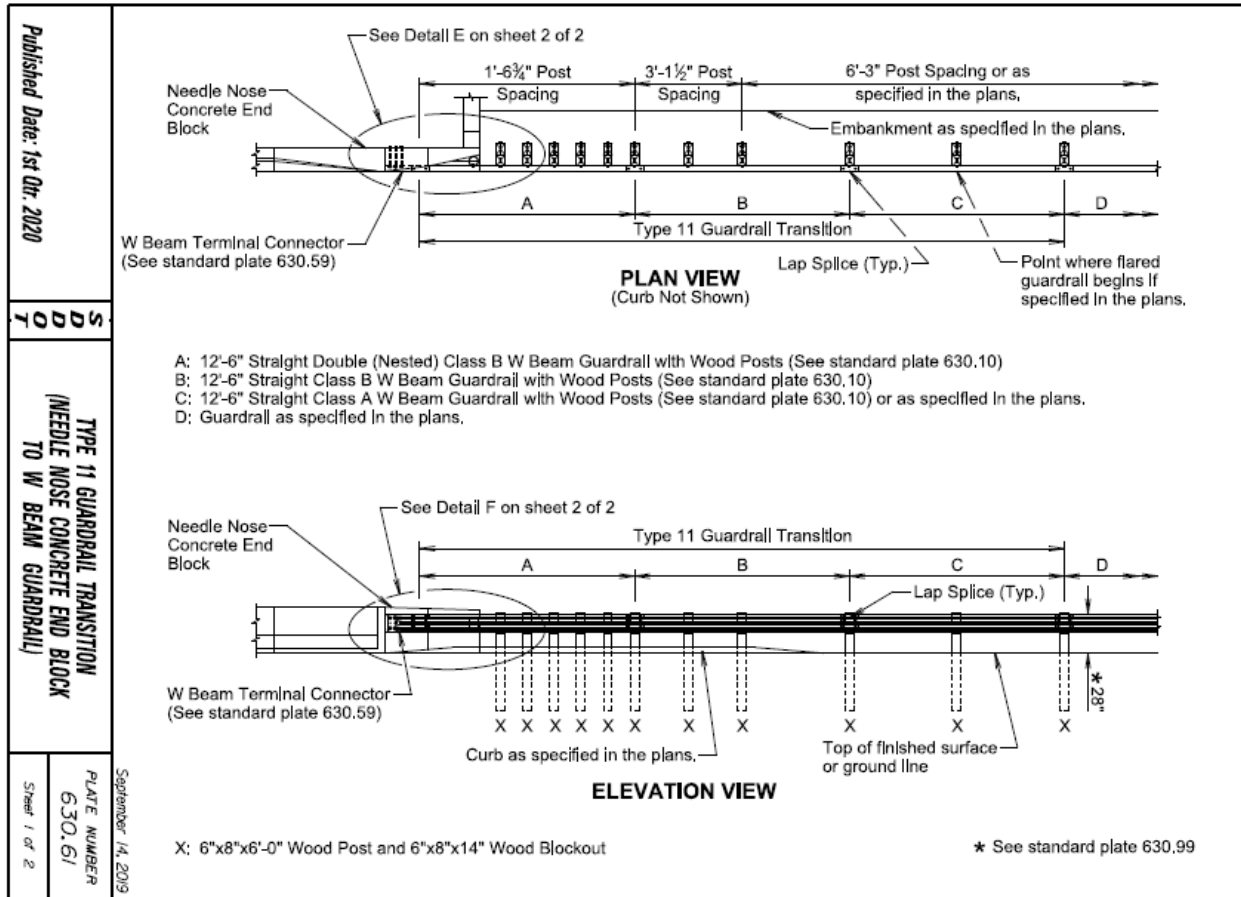


DETAIL J

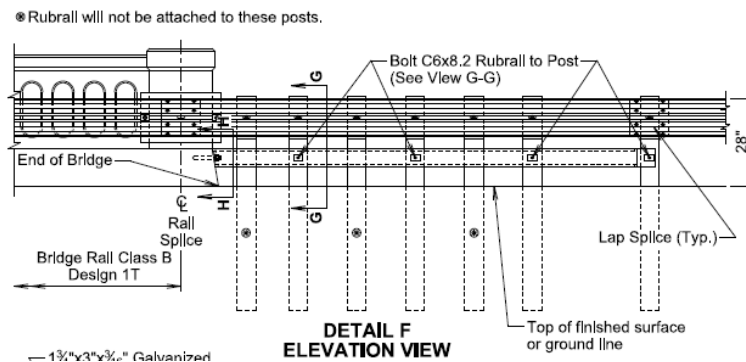
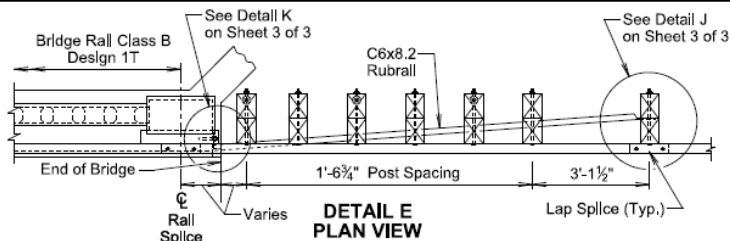
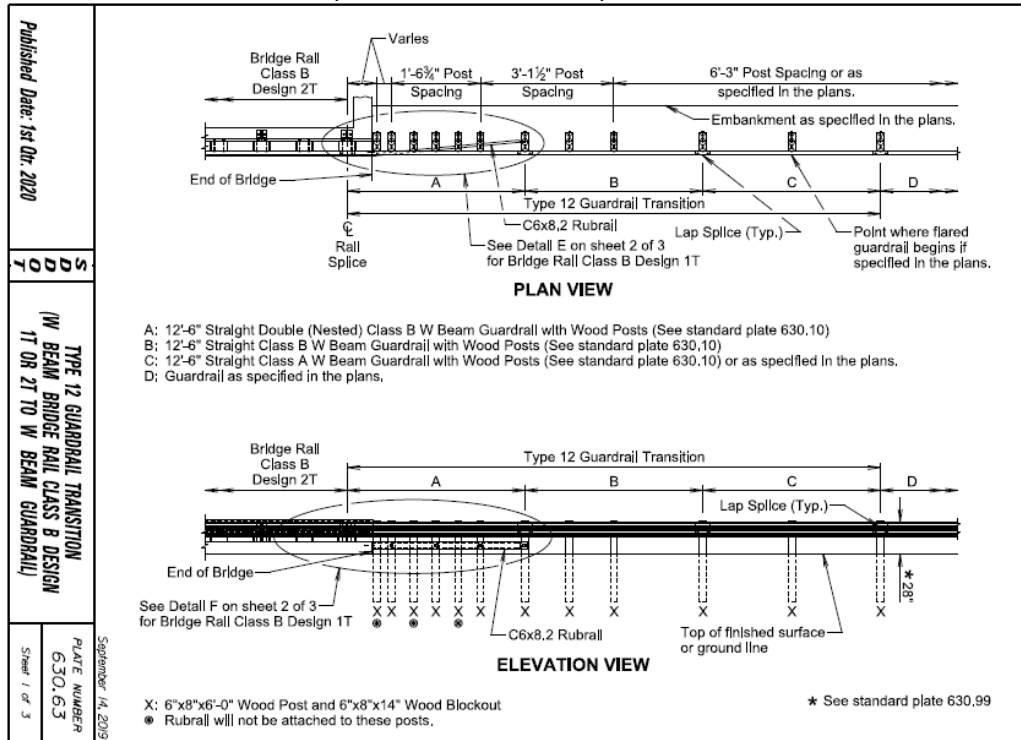
- Type 10 Guardrail Transition (Concrete End Block to W Beam Guardrail): Using this transition in new guardrail designs must be a rare event as this transition was not crash tested to meet the test level 3 crash test requirements of NCHRP 350 or MASH (See APPENDIX A).



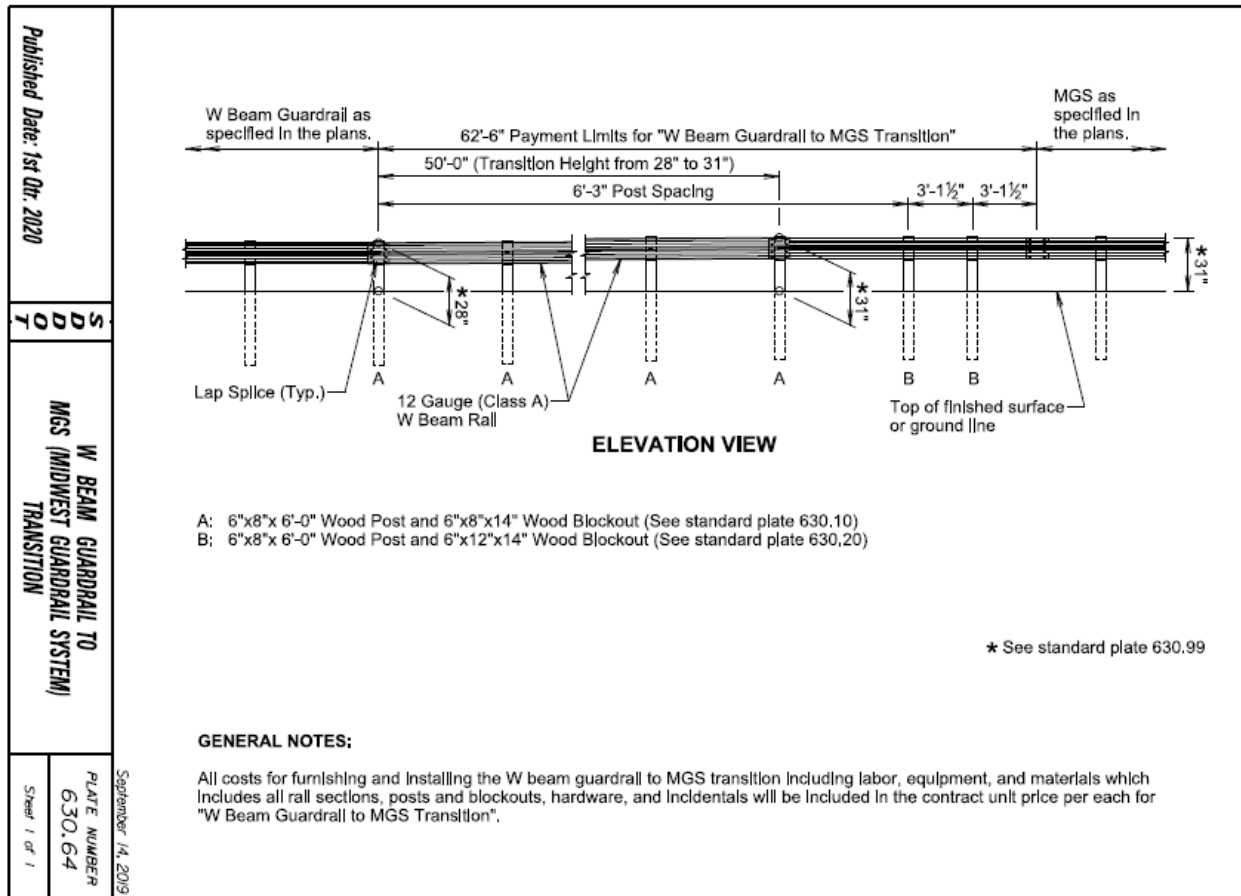
- Type 11 Guardrail Transition (Needle Nose Concrete End Block to W Beam Guardrail): Using this transition in new guardrail designs must be a rare event as this transition was not crash tested to meet the test level 3 crash test requirements of NCHRP 350 or MASH (See APPENDIX A).



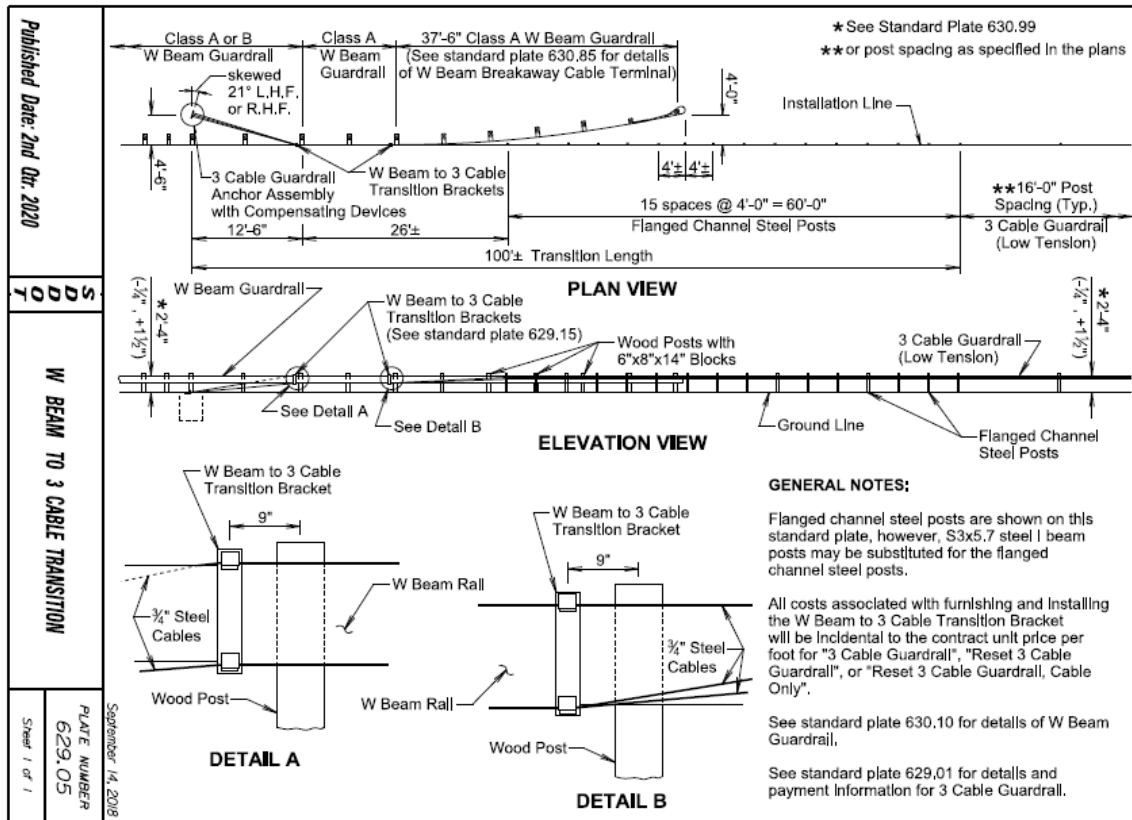
- Type 12 Guardrail Transition (W Beam Bridge Rail Class B Design 1T or 2T to W Beam Guardrail): Using this transition in new guardrail designs must be a rare event as this transition was not crash tested to meet the test level 3 crash test requirements of NCHRP 350 or MASH (See APPENDIX A).



- * W Beam Guardrail to MGS Transition: This transition is used when transitioning from W Beam guardrail to MGS. It is SDDOT preference to transition from W Beam to MGS instead of transitioning from W Beam to 3 cable (low tension) guardrail. MGS meets the test level 3 crash test requirements of MASH while the 3 cable (low tension) guardrail meets the test level 3 crash requirements of NCHRP 350.



- * W Beam Guardrail to Three Cable Guardrail Transition: The W Beam to 3 cable transition uses the Breakaway Cable Terminal (BCT) as the W Beam terminal. This is the ONLY location the BCT is to be used.



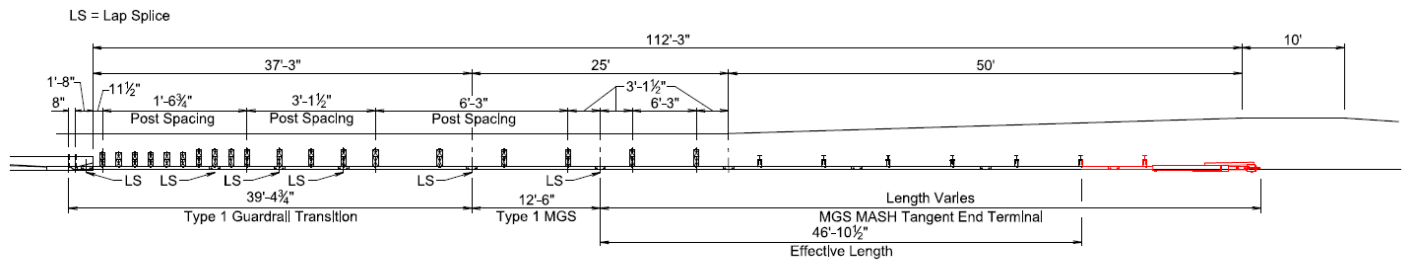
There is currently NO transition available that meets MASH crash testing requirements for transitioning from MGS to High Tension Cable Guardrail. SDDOT investigated this, and it appears it will be years before one can be developed and crash tested to MASH. This is currently being monitored as these would be preferred instead of using the long lengths of steel beam guardrail which tends to increase snow drifting issues at some locations.

There will be some instances where a bridge rail or end block cannot be updated (See flowcharts in APPENDIX A), and the guardrail length attached to the structure that is needed is longer than 200'. In these situations, transitioning to 3 cable guardrail and terminating the cable with the slip base anchor on non-NHS highways would be allowed; however, SDDOT preference would be to transition from the W beam to MGS then use MGS and terminate with the MGS MASH Tangent End Terminal or MGS MASH Flared End Terminal.

There is a test level 2 MASH transition from concrete end block to MGS that was developed through Texas A&M roadside safety pooled fund; however, SDDOT is not utilizing this option at this time.

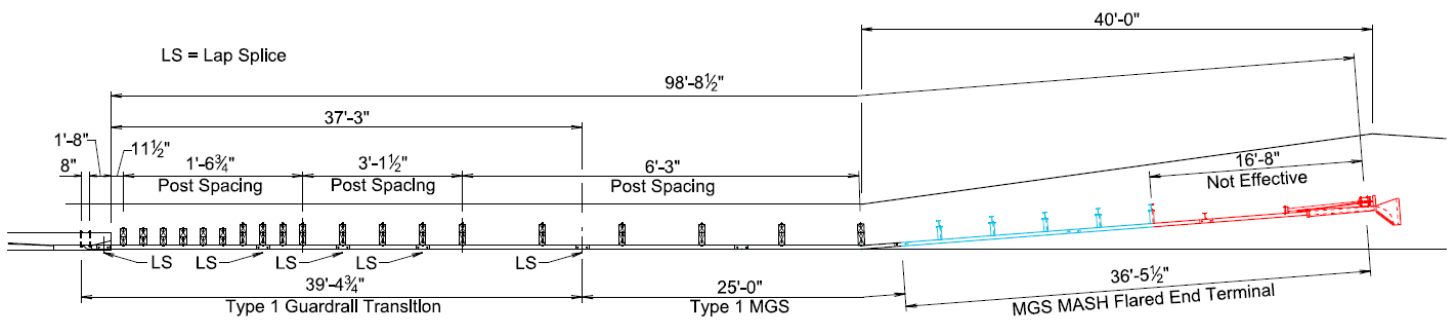
MINIMUM LENGTH GUARDRAIL

If the directional AADT is less than 500, consider using the minimum length guardrail. If minimum length guardrail is used, the SDDOT standard is shown in Figures 10-17 and 10-18. The minimum length guardrail in Figures 10-17 and 10-18 meet the test level 3 crash test requirement of MASH. The old standards that used W beam guardrail is shown in Figure 10-19. See the flowcharts in APPENDIX A for additional guidance.



(The MGS MASH Tangent End Terminal shown is for illustrative purpose only.)

Figure 10-17 Minimum Length of MGS with MGS MASH Tangent End Terminal



(Shown with MFLEAT, MGS MASH Flared End Terminal)
 (MFLEAT Terminal, by Road Systems, Inc., 12" Blocks, drawing name is MFLT-12)

Figure 10-18 Minimum Length of MGS with MGS MASH Flared End Terminal

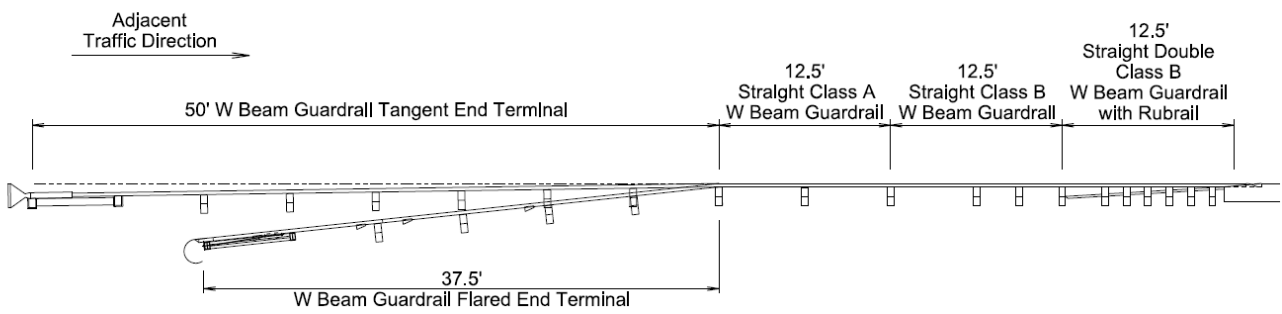
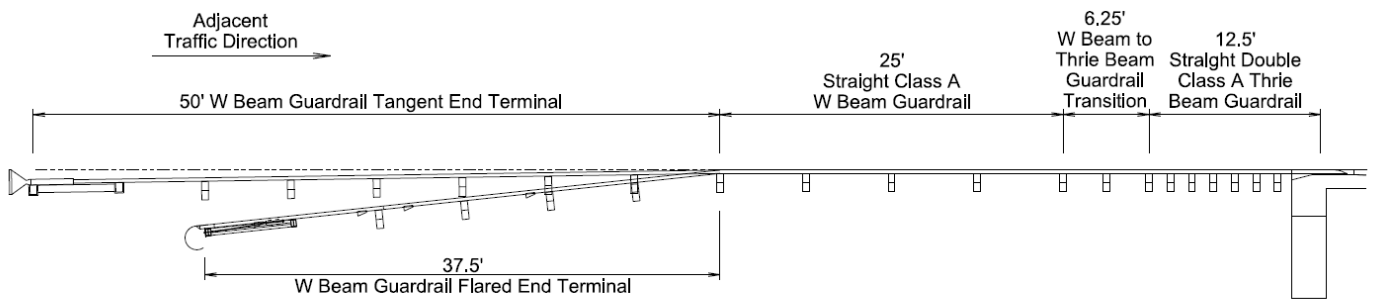


Figure 10-19 Old Minimum Length Guardrail with W Beam Guardrail

TEMPORARY CONCRETE BARRIERS

This section of Chapter 10 is not completed due to current research projects being worked on and that more research/crash testing is necessary for the temporary barrier layouts to fully meet MASH crash testing requirements. Consider using guardrail instead of temporary concrete barriers if needed longer than a construction season.

Research reports regarding the F shape barriers are TRP-03-174-06, TRP-03-202-08, TRP-03-209-09, TRP-03-337-17, and TRP 03-386-19.

The transition from the concrete bridge rail end to the freestanding F shape is not crash tested with a 4" high curb and the F shape barrier placed on top in this scenario would not meet NCHRP 350 requirements.

All temporary concrete barriers are designed to be placed on surfacing as the barriers slide on the surfacing when crashed into (there must be surfacing placed behind the barriers based on the deflection distance). Placing temporary barriers on soil can cause unsatisfactory results if struck due to its probability of tipping. Placing the barriers as shown in the drawing below at the edge of the pavement is not recommended unless the barriers are pinned to the pavement. Recent MASH crash testing revealed that the barriers might be able to be pinned to PCCP (more crash tests needed) but not AC pavement (more development and crash testing necessary).

To improve safety within work zones, temporary or movable concrete barriers may be used. The following provides minimum guidelines on the length of barriers needed, the flare rates and the extent needed. It should be noted that traffic volumes, vehicle speeds, work duration and site geometrics may necessitate something different. Longer work durations, higher speeds or higher traffic volumes may make it desirable to place more barrier or at a flatter flare rate.

Movable concrete barriers should be placed along the site that is being protected from errant vehicles. The designer should be aware of what is being protected and allow for deflection of the barriers where practical (use Table 10-12 for deflection of movable concrete barriers). Barriers were crash tested on paved surfaces; therefore, the barriers should be installed on a paved surface and the paved surface should extend behind the barrier for the design deflection distance based on whether they are pinned or not pinned. SDDOT only allows F shape concrete barriers to be pinned as necessary.

Table 10-12 Deflection of Movable Concrete Barriers

Barrier Type ¹	Approximate Deflection ²	Approximate Deflection ³
F shape	3'-6"	6'-8"
Jersey shape	4'-0"	not available

¹ not pinned to ground or surface

² based on high speed situations where possible impact angles are 20 degrees (NCHRP 350 TL-3)

³ based on high speed situations where possible impact angles are 25 degrees (MASH TL-3)

A basic layout of temporary concrete barriers shown in Figure 10-20 would be such that the barriers would be placed parallel to the lanes adjacent to the protection area and there should be at least 2 parallel barriers before the work area (for equipment and materials storage) and at least 2 parallel barriers after the work area. At the beginning of the first 2 parallel barriers the barriers should flare at a rate of 11:1 (or flatter) back to the edge of roadway or to the outside edge of shoulder (whichever works best for equipment and workers). The barriers should not be flared back past the outside of the shoulder where there would be earthwork and surfacing needed to place the barriers on. There should be 2 parallel barriers prior to the flare and a crash attenuator that meets the crash testing requirements of MASH or NCHRP Report 350, Test Level 3 for posted speeds of 45 mph or greater. A TL-2 MASH or NCHRP 350 crash attenuator may be used for 40 mph posted speed. Where posted speeds are 35 mph or less a sloped end may be used. This would most commonly be found only in urban settings or where a stopped condition is met.

In work zones of a long duration, permanent guardrail installation should be provided. These guidelines are for those locations where it has been determined that movable concrete barriers are warranted. Great care should be taken to ensure that their use will be of a benefit. Information on when to consider temporary barrier can be found in the Work Zone Traffic Control chapter of the SDDOT Construction Manual. In the case of a severe hit, these barriers will deflect and may not always properly redirect a vehicle hitting them.

For urban and suburban projects, use of the temporary concrete barriers should be discussed at the scoping meetings. Depending on the traffic counts, posted speeds, possible edge drop-off conditions, number of intersecting roads, number of approaches, equipment storage, and types of equipment it may be decided to not use temporary concrete barriers. Flare rates for the temporary concrete barriers in urban conditions would vary based on conditions of the project. Flare rates for the barriers should be in the range from 11:1 to 5:1. Refer to Chapter 9 of the current AASHTO publication of the *Roadside Design Guide* regarding use of temporary concrete barriers. The Standards Engineer and Operations Traffic Engineer are other resources to provide help for decisions regarding temporary concrete barrier use in urban and suburban areas.

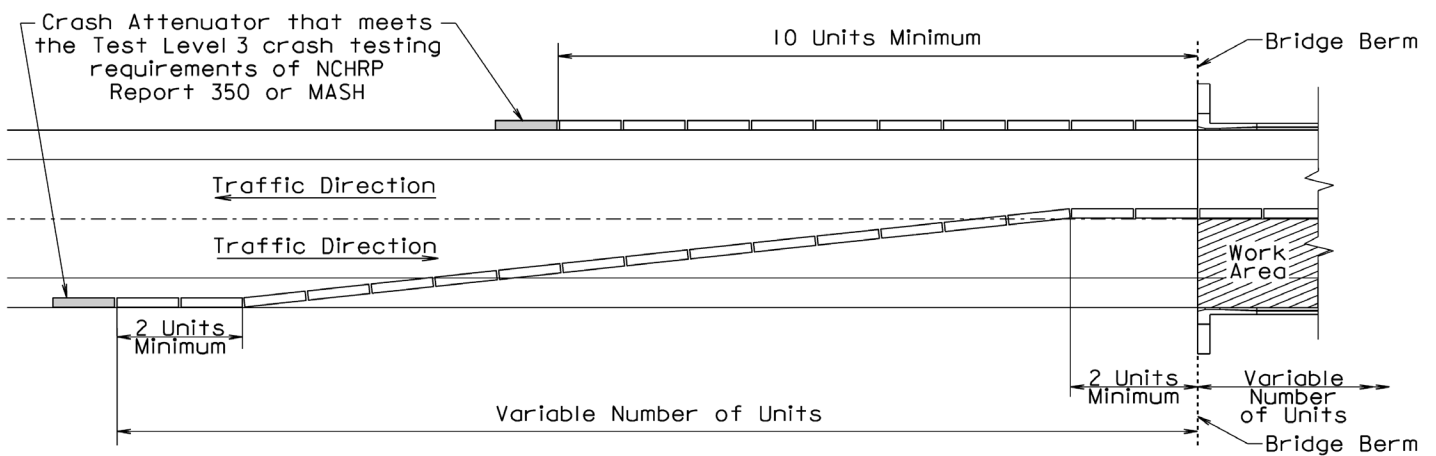


Figure 10-20 Temporary Barrier Design

BID ITEM INFORMATION FOR BARRIER RELATED WORK

Read the specifications sections 629 and 630 as well as the Standard Plates in the 629 and 630 series for additional bid item information regarding measurement and payment as all the items are not listed and described below. Also, remember that notes in the plans overwrite items in the Standard Plates and specifications. This is covered in the specifications. Do not write plan notes that replicate or modify something that is already on the Standard Plates or specifications unless absolutely necessary such as special project conditions. South Dakota typically does not reset guardrail unless project conditions warrant resetting. Steel Beam Rail reset will be in like new condition where there are no tears and no extra holes in the steel beam. High Tension Cable Guardrail that is reset will be in good condition with no broken strands in the cable clusters.

Straight Thrie Beam, MGS, and W Beam Guardrail

Straight Class A or B Thrie Beam and W Beam Guardrail with Wood Posts are paid for by the foot and includes cost for labor, equipment, and materials including all posts, blockouts, steel beam rail, and hardware necessary for the installation of the guardrail. The bid items for Straight Class A or B Thrie Beam and W Beam Guardrail with Wood Posts are used when the guardrail is installed along straight alignments and curved alignments where the radius is greater than 150 feet. The Classes (A or B) stated in the bid items is referring to the Gauge of the rail. Class A is 12 Ga. and Class B is 10 Ga. The Class required can be determined by looking at the Standard Plates in the 630 series. Straight Double Class A or B Thrie Beam and W Beam guardrail with Wood Posts are also paid for by the foot (meter) and includes a double layered (nested) rail as well as the required posts, blockouts, and hardware necessary for installation. MGS is paid for based on the Type shown in the Standard Plates and as specified in the plans.

Curved Thrie Beam, MGS, and W Beam Guardrail

Designer should verify through the Standards Engineer if curved guardrail meets current crash test standard as some systems do not meet MASH crash testing requirements. The bid items with the term "Curved" are used when the steel beam has to be shop bent. If the radius along the installation line of the guardrail is 150 feet or less, then the appropriate bid items regarding Curved Thrie Beam, MGS, and W Beam Guardrail should be used. Payment is the same for these items as the Straight Thrie Beam and W Beam Guardrail as described above. If MGS needs to be installed on a radii less than 150 feet the term "Curved" would be placed before the MGS Type. Example: Curved Type 1 MGS.

MGS MASH Flared or Tangent End Terminal

These are SDDOT standard end terminals. MGS MASH Flared End Terminals and MGS MASH Tangent End Terminals are paid for per each and includes cost for all labor, equipment, and materials including all posts, blockouts, steel beam rail, and hardware associated with the terminal for complete installation of the terminal (payment for these is stated on the corresponding Standard Plates. The terminal will be installed according to the Manufacturer's installation instructions. The type (Flared or Tangent) of end terminal to be used is specified by the Engineer in the plans but is the Contractor's choice from the approved products list. There is one MGS MASH Flared End Terminal and two MGS MASH Tangent End Terminals on the approved product lists.

W Beam Guardrail Flared or Tangent End Terminal

This does not meet current MASH crash testing standards; however, it may be used for certain situations (see Appendix A for guidance). W Beam Guardrail Flared End Terminals and W Beam Guardrail Tangent End Terminals are paid for per each and includes cost for all labor, equipment, and materials including all posts, blockouts, steel beam rail, and hardware associated with the terminal for complete installation of the terminal. The terminal will be installed according to the Manufacturer's installation instructions. The type (Flared or Tangent) of end terminal to be used is specified by the Engineer in the plans but is the Contractor's choice from the approved products list. There are two flared end terminals and one tangent end terminal on the approved product lists.

Guardrail Transitions

See Standard Plates in 630 series regarding all transitions as the payment information is shown on the Standard Plates.

Beam Guardrail Post and Block

Cost for Beam Guardrail Posts and Blocks are normally included in the cost of the guardrail unless special circumstances require additional posts to be placed or if the rail is being reset from a previous location. In these locations, the posts and blocks are paid for on a per each basis.

W Beam Guardrail to Three Cable Guardrail Transition

This does not meet current MASH crash testing standards; however, it may be used for certain situations (see Appendix A for guidance). The W Beam Guardrail to Three Cable Guardrail Transition is not a pay item. The portions of the transition will be paid for separately. The transition section would require bid items for the W Beam Guardrail, W Beam Guardrail Breakaway Cable Terminal, 3 Cable Guardrail, and the 3 Cable Guardrail Anchor Assembly. See Standard Plates 629.01, 629.05, 630.31, 630.32, and 630.47.

Three Cable Guardrail (Low Tension)

This does not meet current MASH crash testing standards; however, it may be used for certain situations (see Appendix A for guidance). 3 Cable Guardrail (Low Tension) is paid for by the foot and includes cost for labor, equipment, and materials including all posts, cables, and hardware necessary for the installation of the 3 cable guardrail.

High Tension Cable Guardrail and End Terminal Anchorages

This is SDDOT standard. High Tension Cable Guardrail is paid for by the foot and includes cost for labor, equipment, and materials including all posts, cables, and hardware necessary for the installation of the High Tension Cable Guardrail. See Section B – Grading Notes for more information regarding High Tension Cable Guardrail and end terminals payment.

Three Cable Guardrail Anchor Assembly

This does not meet current MASH crash testing standards; however, it may be used for certain situations (see Appendix A for guidance). 3 Cable Guardrail in the 3 Cable Guardrail Anchor Sections is paid for by the foot and includes cost for labor, equipment, and materials including all posts, cables, and hardware necessary for the installation of the 3 cable guardrail. The 3 Cable Guardrail Anchor Assembly is paid for per each and includes cost for labor, equipment, and materials including the concrete anchor, cable anchor bracket, compensating device, steel turnbuckle cable assembly, and necessary hardware for installation. See Standard Plate 629.01.

Concrete Barrier End Protection

The Concrete Barrier End Protection is paid for per each and includes all costs for furnishing and installing the crash cushion including the anchoring pad, anchors for connection to the pad, transitions to the concrete barrier, materials, labor, equipment, and incidental items. The bid item for this is used in permanent concrete barrier end protection locations. The crash cushion will be a MASH device that is designed for the traffic condition it is being used for. See Section B – Grading Notes regarding the Permanent Concrete Barrier End Protection plan note for more information.

Traffic Control Movable Concrete Barrier

The Traffic Control Movable Concrete Barrier is paid for per each and includes all costs to pick up the barrier from the SDDOT maintenance yard, haul it to the site, place it for traffic control, shift the barrier as necessary (not load & haul), and return it to the SDDOT maintenance yard. This bid item will pay for the total number of barriers brought to the project and will be used with Standard Plate 628.01 only.

Remove and Reset Traffic Control Movable Concrete Barrier

The Remove and Reset Traffic Control Movable Concrete Barrier is paid for per each and includes all costs when the barriers need to be moved and reset on the project for a different traffic control phase. The moving of the barrier will be paid for each time it is needed to be removed and reset by utilizing this bid item. Small shifts in the placement of the barrier (not requiring loading of the barriers for movement), would not constitute the use of this item.

Temporary Concrete Barrier End Protection

The Temporary Concrete Barrier End Protection is paid for per each and includes all costs to supply, set-up, and remove the temporary crash cushions. The quantity would be the maximum number used at any one time on a project. The crash cushion must meet test level 3 requirements.

Remove and Reset Temporary Concrete Barrier End Protection

The Remove and Reset Temporary Concrete Barrier End Protection is paid for per each and includes all costs when the end protection needs to be moved to a new location, the removal, and resetting of the end protection. This item will be used each time it is moved and reset.

Concrete Barrier End Protection Module Set or Repair Kit

The Concrete Barrier End Protection Module Set or Repair Kit is paid for per each and includes all costs for furnishing and delivering the extra set(s) of modules or replacement kit(s) to the required Area Office or Region Office. This item is not used very often as it may be better to purchase this through the SDDOT than through the Contractor. If this bid item is used on a Federal Aid project, the bid item should be nonparticipating. See Section B – Grading Notes regarding the Permanent Concrete Barrier End Protection plan note for more information.

Temporary Concrete Barrier End Protection

When concrete barrier end protection is necessary during construction, the Temporary Concrete Barrier End Protection bid item should be used. Temporary Concrete Barrier End Protection is paid for per each and includes all costs for furnishing, installing, and maintaining the crash cushion including the anchoring pad (if necessary), anchors for connection to the pad, transitions to the concrete barrier, materials, labor, equipment, and incidental items. The crash cushion will be a MASH or NCHRP 350 device that is designed for the traffic condition that it is being used for. Eventually all of these will be only MASH, contact the Operations Traffic Engineer for more information. The Contractor will retain ownership of the crash cushion at the completion of the project.

Temporary Concrete Barrier End Protection Module Set or Repair Kit

The Concrete Barrier End Protection Module Set or Repair Kit is paid for per each and includes all costs for storing the module set or repair kit during construction, replacing the module set or repair kit, or refurbishing the crash cushion including equipment, materials, and labor. This item is used when the Area Office requests it and they provide the quantity necessary to be on hand during a construction project. This item is used coincidentally with the Temporary Concrete Barrier End Protection bid item. If a crash cushion is impacted or damaged during the project, the Contractor will reset or refurbish the crash cushion within 24 hours after the impact or damage has occurred. The Contractor will retain ownership of the temporary concrete barrier end protection module set or repair kits at the completion of the project.

Rubrail

This does not meet current MASH crash testing standards; however, it may be used for certain situations (see Appendix A for guidance). Rubrail is only used where W beam guardrail connects onto a bridge (exception is where attached to a needle nose endblock). The rubrail is used to avoid the snagging of the car on the concrete end block of the bridge. The rubrail is paid for on a per foot basis. Current MASH tested bridge railing is designed to connect to double (nested) three beam guardrail making the use of rubrail unnecessary.

Remove Thrie Beam or W Beam Guardrail for Reset and Reset Thrie Beam or W Beam Rail

Reset Thrie Beam or W Beam Rail is paid for in the same manner as the new guardrail (per foot). Steel beam guardrail will typically require new posts and blockouts whereas three cable guardrail posts can be reused only if they meet current specifications. When resetting guardrail, the designer must include Bid Items to remove the item for reset as well as Bid Items to reset the rail in the new location. When new posts and blocks are necessary (most of the time) the bid item for Beam Guardrail Post and Block should be used. The bid items for Reset Thrie Beam Guardrail with Wood Posts and Reset W Beam guardrail with Wood Posts should only be used when the whole system is being reset which includes resetting the wood posts (this is not done very often, only when the posts are in the ground for a short time such as less than two years).

BARRIER DESIGN EXAMPLES

At the end of each example below under Design Layout, refer to Chapter 18 - Plans Assembly for proper plan preparation of Guardrail Layouts.

Design Example 1: Guardrail at Twin Bridges of Divided Highways

Design Factors:

- Highway: Interstate (NHS, see Guidance for Determining Bridge Rail Attachment Upgrades flowchart in Appendix A)
- Roadside Obstacles: Bridge and Steep Transverse Slope Between Structures (Median) and Steep Inslope (Right Side)
- AADT (directional) = 8200
- Design Speed = 80 mph
- Roadway Characteristics: Median Shoulder (4'), Right Side Shoulder (10'), 2- 12' Lanes with One-Way Traffic Direction
- Bridge Characteristics: 40' Width, Concrete End Blocks, Approach Slab with Drop Inlets
- Reconstruction Project
- Clear Zone: Median (80'), Right Side (30')
- Protection Limit: Use Clear Zone Based on Obstacles Present
- Runout Length: 470'
- Flare Rate: Using semi-rigid barrier (MGS), therefore, use 18:1 Flare Rate on median side. Do not flare guardrail on the right side shoulder because fill height is higher than 10'. If there have been excessive snow drifting in this area, consider flaring the guardrail.

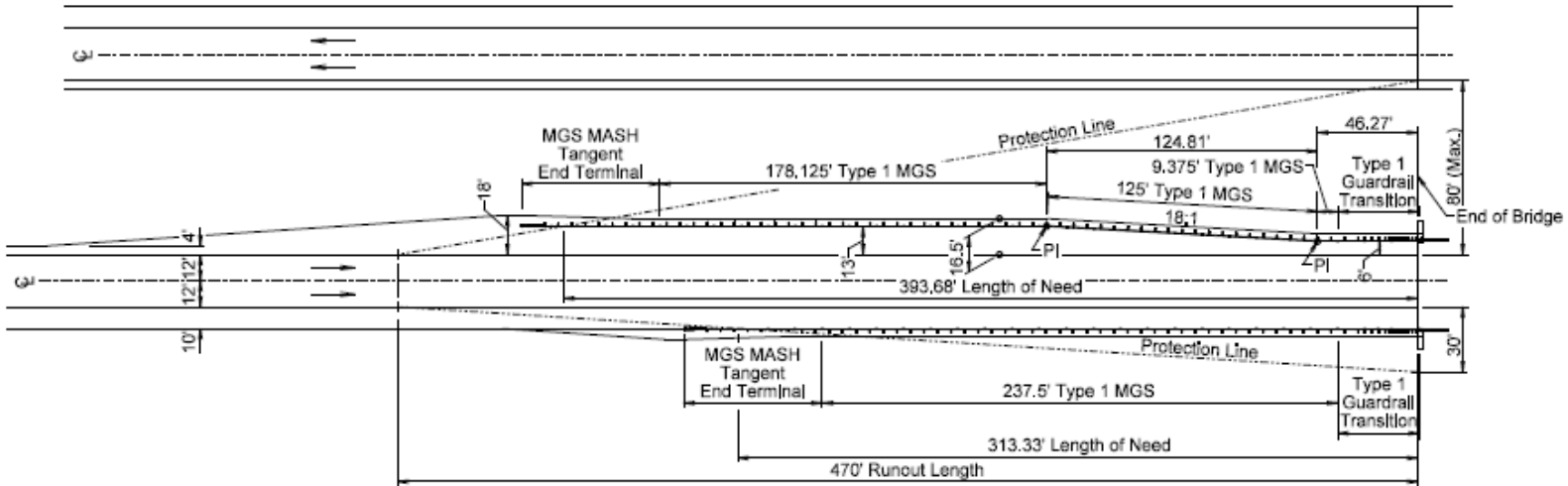
Design Steps:

1. The first step after acquiring the Design Factors is to verify which crash testing standard should be used for the guardrail design. Since this example is a design on the Interstate (NHS) the design will need to meet the MASH crash testing standard (see flowcharts in APPENDIX A).
2. Draw the "Protection Lines" (see section on BARRIER DESIGN STEPS).
3. Review the bridge end block and Standard Plates to determine which guardrail transition should be used. The five-bolt connection in the end block is at a different location depending on the era when it was originally constructed. Review location and depth of drop inlets in the bridge approach slab as a post should not interfere with the cross pipe outlet of the drop inlet. The sleeper slab underdrain pipe is another item that should be accounted for when laying out the location of the guardrail posts.

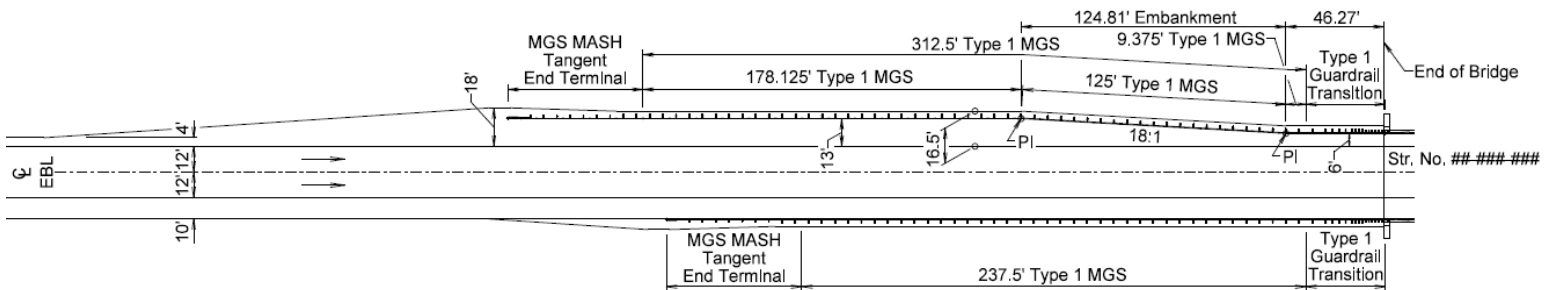
It is preferred that a minimum of 1' of clearance is maintained from the top of the cross pipe to the bottom of the guardrail post. A Type 3 Guardrail Transition was developed to aid in not having post interference with a cross pipe; therefore, it is an option for the transition. Using the Steel Beam Guardrail cell library place the proper transition at both of the end blocks.

4. On the median side, add a cell representing the Type 1 MGS. Since it is standard practice (due to snow drifting concerns) to flare the guardrail on the median side, the cell should be modified and flare a portion of the rail at the 18:1 flare rate. The location of the PI or point to begin flaring the guardrail is noted on the Standard Plate regarding the transition. (HINT: whenever modifying a cell to begin or end a flare, always rotate the selected portion of the cell about the PI located at the front face of the rail.)
5. Place multiple Type 1 MGS cells at an 18:1 flare. The lateral distance the guardrail flares into the median should be determined such that the proper embankment width and inslopes could be placed so that the drainage in the median would not be affected. For an 80' median, flare the guardrail to a lateral offset of 13' or less to avoid impacts to median drainage.
6. Once the guardrail achieves the desired lateral offset, run the guardrail parallel with the roadway. The cell would have to be modified where the PI will be located. The PI would be located at a post.
7. Place multiple Type 1 MGS cells parallel to the roadway. Using the MGS MASH Tangent End Terminal with Embankment Cell, gage where the Type 1 MGS will end. The Type 1 MGS will have to end such that the whole length of the Type 1 MGS is at a 12.5' increment. The MGS MASH Tangent End Terminal cell has a different color (red) to indicate the portion which is not effective (gating portion). The non-effective portion must fall outside of the protection line.
8. On the right side shoulder line, after the transition was drawn, begin placement of Type 1 MGS cells and do similar to what is described above in step 7.
9. After guardrail and embankments are drawn, finish labeling the guardrail elements in the layout. Be sure to provide a tie to the topography as to where the guardrail is to be placed. The tie can be stationing and offset, dimensioning from a structure element, or a tie to the structure. Place the drawing on a plan sheet for inclusion in the plans. Refer to Chapter 18 – Plans Assembly for an example guardrail layout.
10. Tabulate the necessary bid items and quantities for the plans.

Note: Regarding the layout placed in the plans, be sure to label the required inslopes on the layout if not covered elsewhere in the plans or Standard Plates. If the inslopes are different than what is stated on the Standard Plates, be sure to note that the inslopes will be built in accordance with the guardrail layout and not the Standard Plate. The dimension lines should be parallel with the face of the rail because guardrail is measured at the face of the guardrail.



Design Working Drawing



Plans Layout Drawing

Design Example 2: High Tension Cable Guardrail in the Median of Divided Highways and Steel Beam on Outside Shoulder

Design Factors:

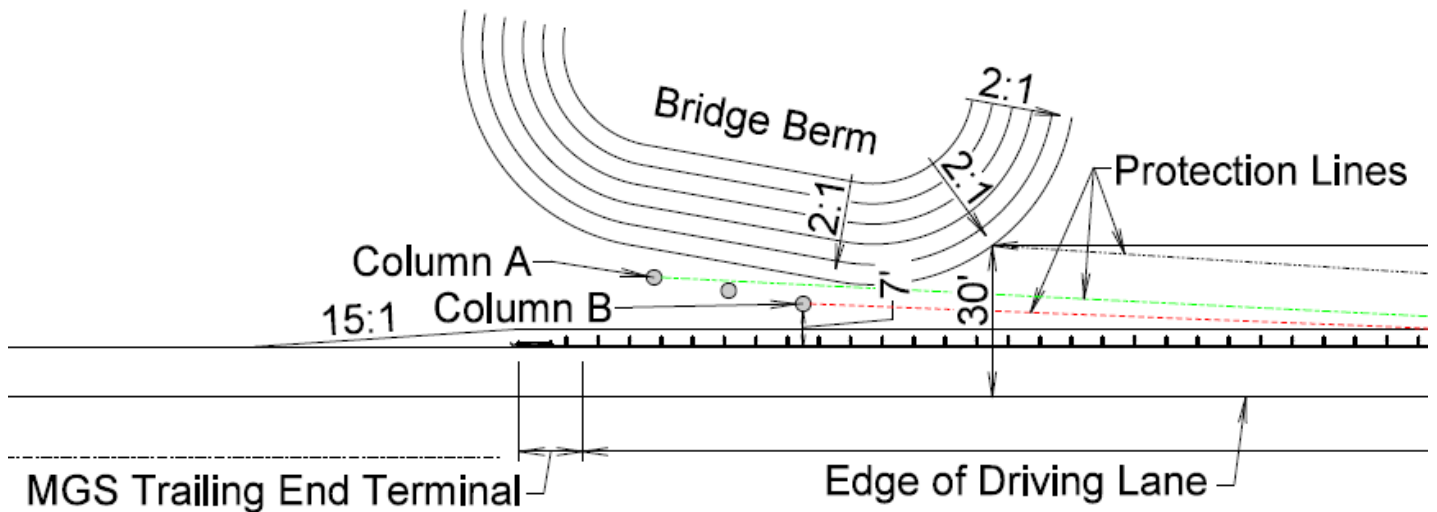
- Highway: Interstate (NHS)
- Roadside Obstacles: Bridge Columns in the Median
- AADT (directional) = 9,600
- Design Speed = 80 mph
- Roadway Characteristics: Median Width (54'), Median Shoulder (4'), Right Side Shoulder (10'), 2- 12' Lanes with One-Way Traffic Direction
- Reconstruction Project
- Clear Zone: Median Obstacle (40')
- Protection Limit: Use Obstacles Present
- Runout Length: 470'
- Flare Rate: Do not flare cable barrier

Design Steps:

1. The first step after acquiring the Design Factors is to verify which crash testing standard should be used for the guardrail design. Since this example is a design on the Interstate (NHS) the design will need to meet the MASH crash testing standard (see Guidance for Determining Bridge Rail Attachment Upgrades flowchart in Appendix A).
2. Draw the "Protection Lines" (see section on BARRIER DESIGN STEPS) for all obstacles (columns, berms culverts, etc.) to determine the maximum protection needed. See Design Working Drawings 1 & 2.
3. Place MGS Trailing End Terminal cell per direction provided in Figure 10-9.
4. Place multiple Type 1 MGS cells parallel to the roadway. Using the MGS MASH Tangent End Terminal with Embankment Cell, gage where the Type 1 MGS will end. The Type 1 MGS will have to end such that the whole length of the Type 1 MGS is at a 12.5' increment. The MGS MASH Tangent End Terminal cell has a different color (red) to indicate the portion which is not effective (gating portion). The non-effective portion must fall outside of the protection line.
5. Draw the Protection Line at (40' CZ) at the front face of the nearest obstacle for the approach side of the median shoulder. See Design Working Drawings 3 & 4.
6. To start the layout of the High Tension Cable Guardrail, place the High Tension Cable Guardrail Anchor Assembly cell parallel the road at the 51' non-effective

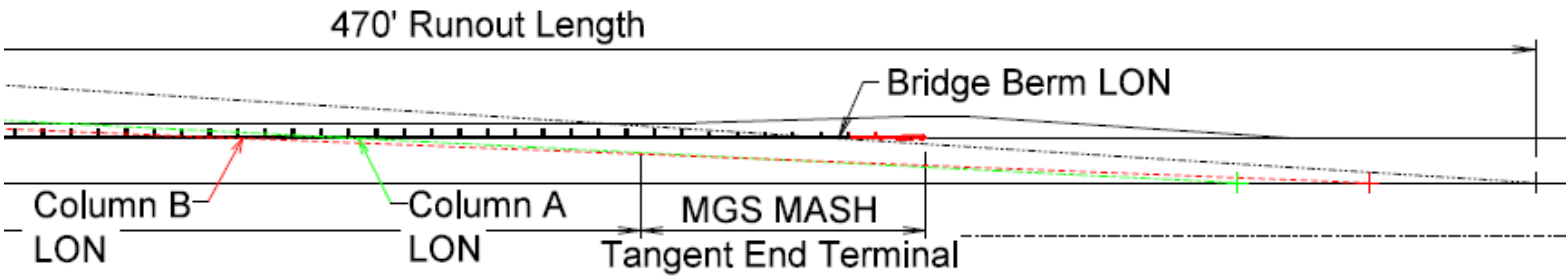
length from the departure side of the furthest downstream obstacle. See Design Working Drawing 3. (Note: It is preferred to start at the departure end and layout the high tension cable guardrail toward the approach end. Any extra length would be on the approach end where there is a greater effective area.)

7. Place multiple High Tension Cable Guardrail cells parallel to the roadway. Using the High Tension Cable Guardrail Anchor Assembly with Embankment Cell, gage where the High Tension Cable Guardrail will end. The High Tension Cable Guardrail Anchor Assembly cell has a different color (red) to indicate the portion which is not effective (gating portion). The non-effective portion must fall outside of the protection line.
8. After guardrail and embankments are drawn, finish labeling the guardrail elements in the layout. See Final Design Working Drawing. Be sure to provide a tie to the topography as to where the guardrail is to be placed. The tie can be stationing and offset, dimensioning from a structure element, or a tie to the structure. Place the drawing on a plan sheet for inclusion in the plans. Refer to Chapter 18 – Plans Assembly for an example guardrail layout.
9. Tabulate the necessary bid items and quantities for the plans.



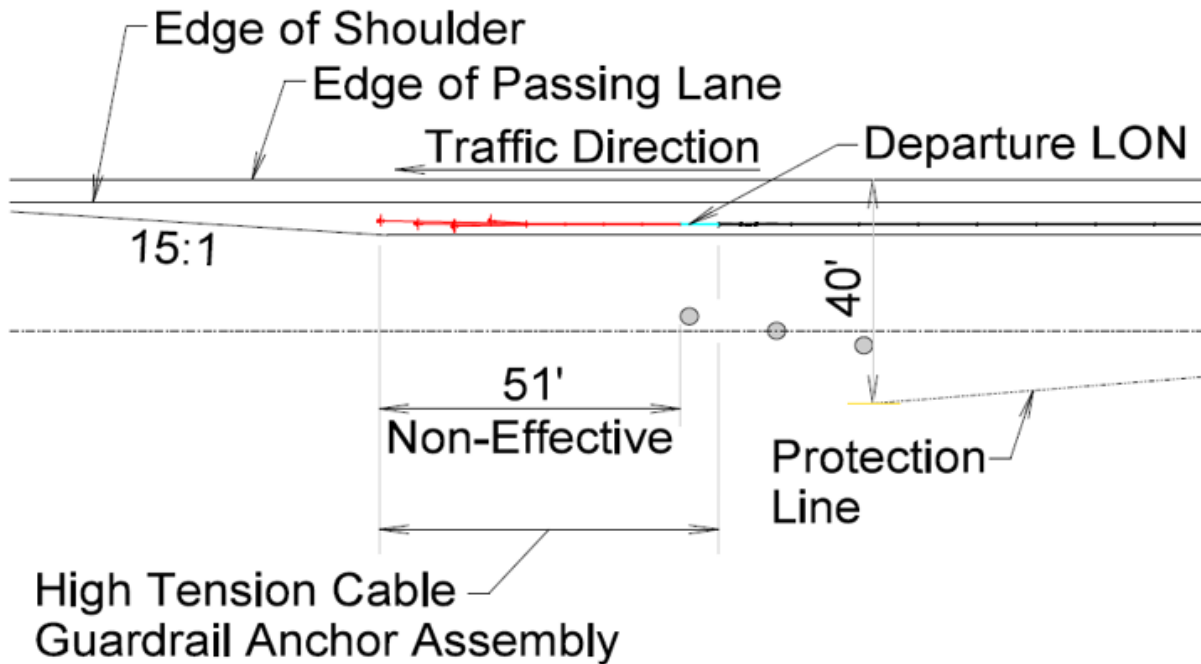
Drawing above illustrates the various checks (green line, red line, and angled black dotted line at end of 30' cz dimension) for design runout to determine the length of need (LON).

Design Working Drawing 1



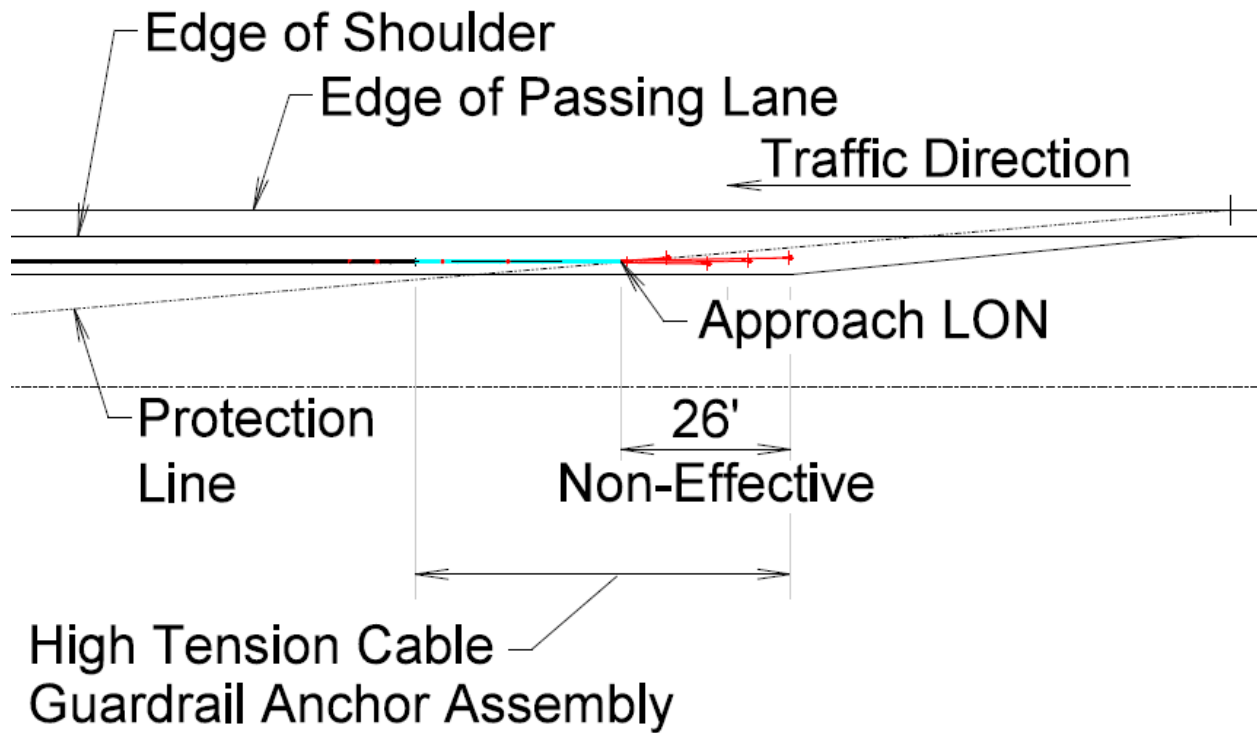
Drawing above illustrates the other end at LON points (the colored lines with arrows refer to the same LON checks in drawing at top of page). The black dotted line controls the design and LON.

Design Working Drawing 2



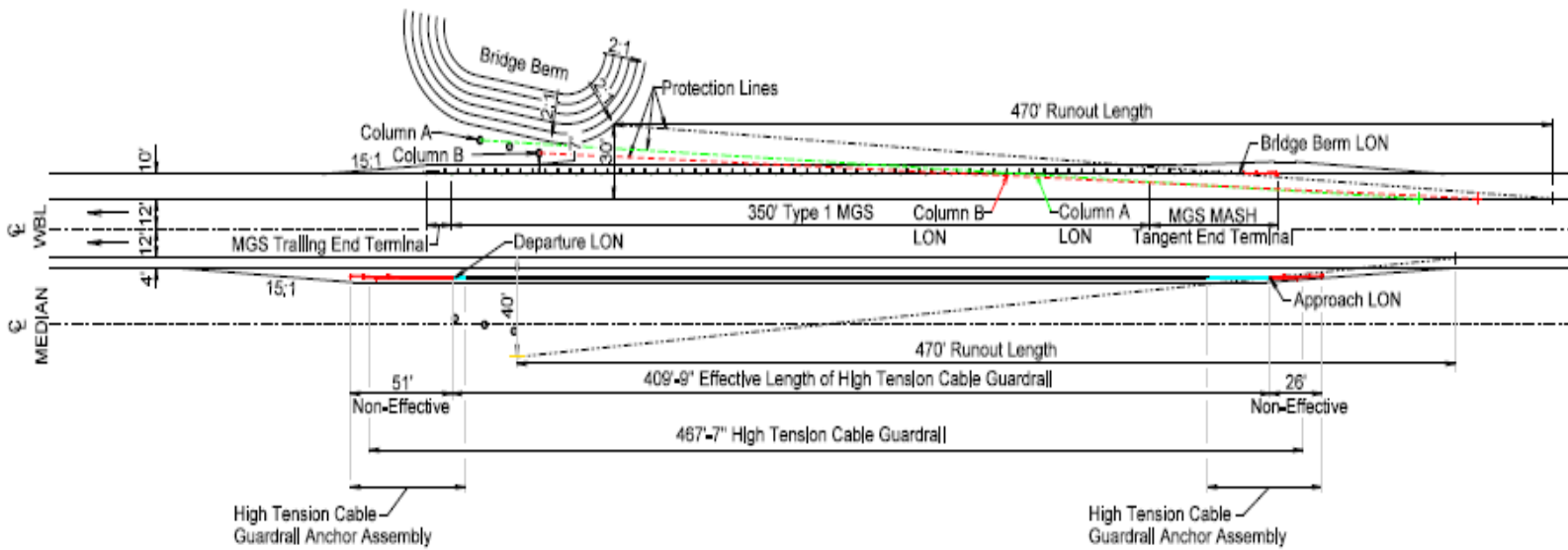
Drawing above illustrates the various median checks (red line and angled black dotted line) for design runout to determine LON. Notice that the departure end of high tension cable guardrail has a different LON point of which the cable is non-effective on the end. The Departure LON should line up with the obstacle as this is a deflection issue.

Design Working Drawing 3



In the drawing above the controlling LON is based on the black dotted line. Notice the approach LON and that the non-effective portion is 26'.

Design Working Drawing 4



Complete design drawing above. The layout in the plans would not have the runout lines, cz dimension, and protection lines shown.

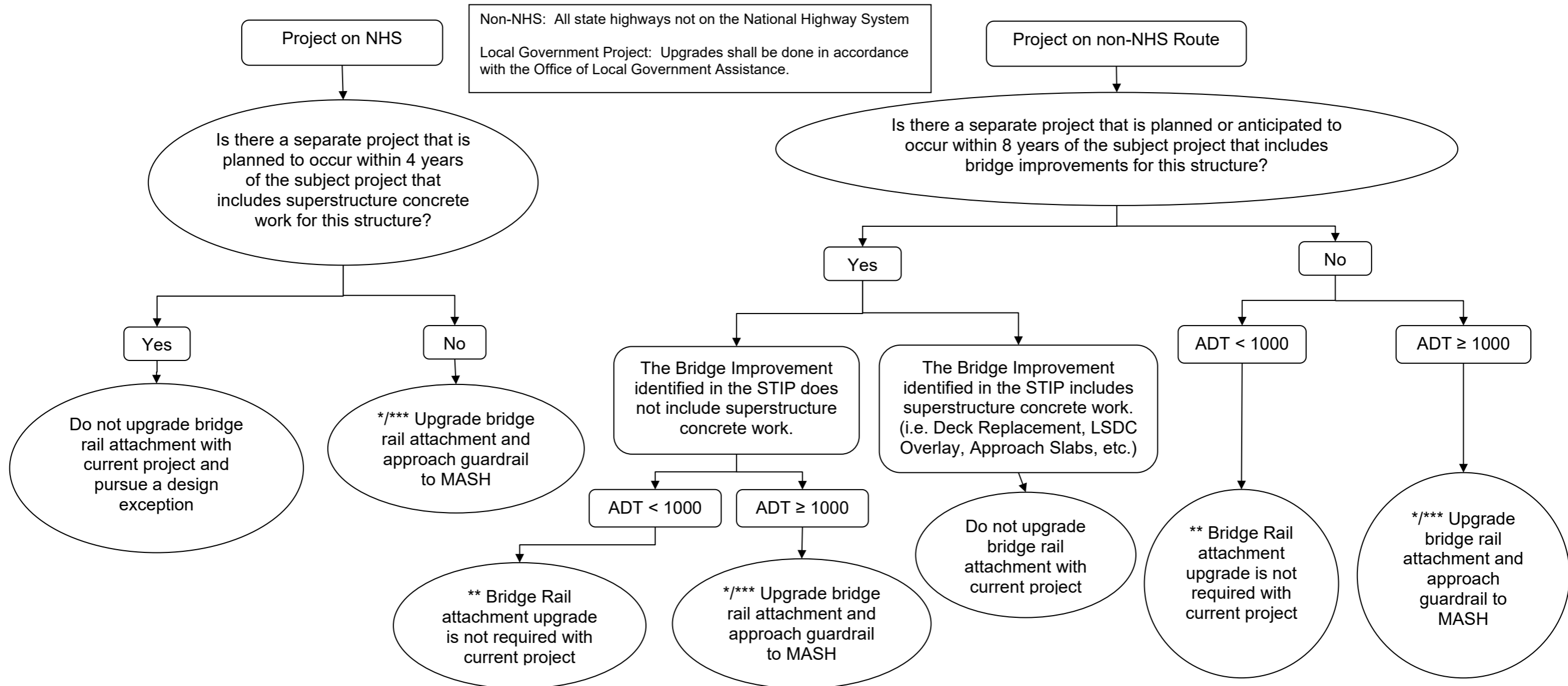
Final Design Working Drawing

APPENDIX A CHAPTER 10

FLOWCHARTS FOR BRIDGE RAIL ATTACHMENT UPGRADES

The following flowcharts have been developed to provide guidance that should be considered as bridge rail attachment upgrades are evaluated. The basis of the information originates from MASH criteria; however, engineering judgement was used to consider potential variables that could be encountered, which are not specifically addressed within published criteria. Each decision may require further site-specific analysis and/or engineering judgement.

**Guidance for Determining Bridge Rail Attachment Upgrades for the Following Project Types:
Asphalt Concrete Resurfacing/Surfacing, Shoulder Widening, and Stand-alone Guardrail**

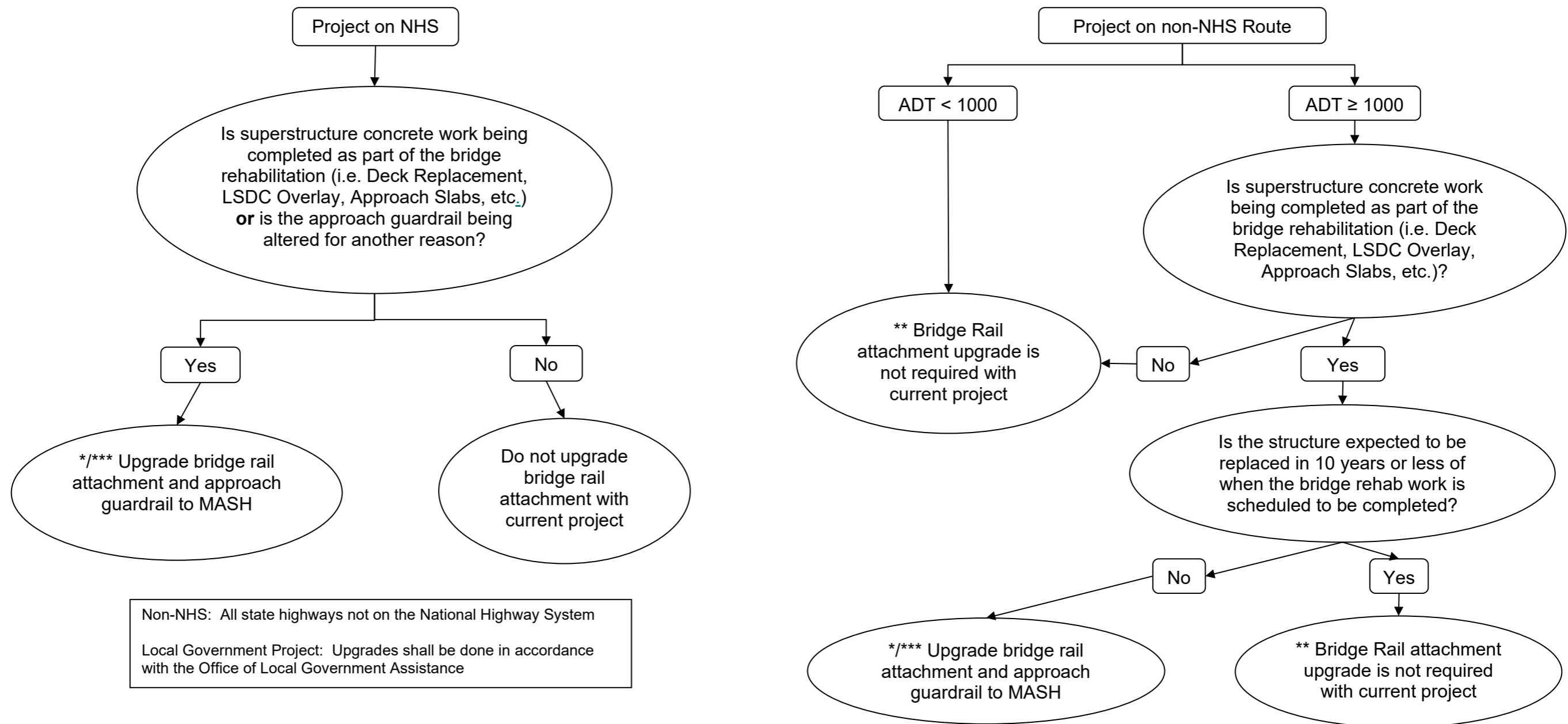


* Verify bridge can accommodate (withstand loading) new concrete bridge rail or new concrete end blocks without requiring deck replacement. If deck replacement and/or other work would be required, consider pursuing a Design Exception.

** A bridge that currently has W-Beam bridge rail should be evaluated for a possible upgrade to thrie beam based on factors such as accident history, age of structure, ADT (near threshold), etc.

*** If a concrete end block with thrie beam attachment is currently in place, top of guardrail height needs to be checked to ensure it will be within tolerance (31" +/-2"). If not within tolerance, consider a relocated 5-bolt connection location on the existing end block. If a relocated 5-bolt connection location will not work, a new concrete end block should be installed. If the bridge has an existing thrie beam attachment and the approach guardrail is less than 6 years old, consider resetting the existing approach guardrail instead of upgrading. For this situation, a Design Exception, referencing useful life of the existing guardrail system, will be needed if on the NHS.

Guidance for Determining Bridge Rail Attachment Upgrades on Bridge Rehabilitation Projects



- * Verify bridge can accommodate (withstand loading) new concrete bridge rail or new concrete end blocks without requiring deck replacement. If deck replacement and/or other work would be required, consider pursuing a Design Exception.
- ** A bridge that currently has W-Beam bridge rail should be evaluated for a possible upgrade to thrie beam based on factors such as accident history, age of structure, ADT (near threshold), etc.
- *** If a concrete end block with thrie beam attachment is currently in place, top of guardrail height needs to be checked to ensure it will be within tolerance (31" +/-2"). If not within tolerance, consider a relocated 5-bolt connection location on the existing end block. If a relocated 5-bolt connection location will not work, a new concrete end block should be installed. If the bridge has an existing thrie beam attachment and the approach guardrail is less than 6 years old, consider resetting the existing approach guardrail instead of upgrading. For this situation, a Design Exception, referencing useful life of the guardrail system, will be needed if on the NHS.

APPENDIX B CHAPTER 10

BASIC DIFFERENCES OF NCHRP 350 AND MASH CRASH TESTING STANDARDS, AND OTHER CRASH TESTING INFORMATION REGARDING MASH

The following is the history of crash testing guidance:





- 1962 Highway Research Correlation Services Circular 482, 1 page
- 1974 NCHRP Report 153, Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances, 16 pages
- 1980 NCHRP Report 230, Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances, 36 pages
- 1993 NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features, (135 pages)
- 2009 AASHTO Manual for Assessing Safety Hardware, 2009 Edition (MASH)
- 2016 AASHTO Manual for Assessing Safety Hardware, 2016 Edition (MASH)



NCHRP 350 Pickup Truck
4,409 lb

MASH Pickup Truck
5,000 lb

The following table is a comparison of NCHRP 350 vehicles to MASH 2009 vehicles:

VEHICLE CLASS	NCHRP 350	MASH 2009
Small Car 	820C Weight: 1,809 lb	1100C Weight: 2,240 lb
Pickup Truck 	2000P Weight: 4,409 lb	2270P Weight: 5,000 lb
Single Unit Truck 	8000S Weight: 17,636 lb	10000S Weight: 22,000 lb
Tractor Trailer 	36000V Weight: 79,366 lb	36000V Weight: 79,300 lb

The table above represents the basic changes from the NCHRP 350 vehicles to MASH 2009 vehicles. Another car used in some test configurations in MASH is a mid-sized passenger vehicle (1500A) weighing 3,300 pounds. More information about when to use the 1500A vehicle can be found in MASH 2009.

The passenger vehicles used in the MASH crash tests are 6 years old or newer. The heavy trucks used are typically older models as using newer heavy trucks would be cost prohibitive.

The following table is a comparison of NCHRP 350 and MASH 2009 Impact Conditions:

TEST LEVEL	TEST VEHICLE	NCHRP 350	MASH 2009
TL-3	Small Car	Speed: 62 mph Angle: 20°	Speed: 62 mph Angle: 25°
	Pickup Truck	Speed: 62 mph Angle: 25°	Speed: 62 mph Angle: 25°
TL-4	Single Unit Truck	Speed: 50 mph Angle: 15°	Speed: 56 mph Angle: 15°
TL-5	Tractor Trailer	Speed: 50 mph Angle: 15°	Speed: 50 mph Angle: 15°

Note: If roadside safety hardware met the crash testing requirements of Test Level 5 in NCHRP 350, then it would also meet the Test Level 5 crash testing requirement of MASH.

The following table is a comparison of NCHRP 350 and MASH 2009 regarding Other Impact Conditions:

PARAMETER	NCHRP 350	MASH 2009
Impact Angle for Pickup Truck Length of Need Test on Terminals and Crash Cushions	Angle: 20°	Angle: 25°
Impact Angle for Gating Terminals and Crash Cushions	Angle: 15°	Angle: 5°
Intermediate Test Vehicle	None	1500A Sedan Weight: 3,300 lb
Support Structure and Work Zone Traffic Control Device Testing	Small Car Impacts Only	Small Car and Pickup Truck Impacts

The following table is a basic comparison of NCHRP 350 and MASH 2009 regarding modifications to the evaluation criteria:

PARAMETER	NCHRP 350	MASH 2009
Maximum Roll/Pitch Angles	No Rollover	< 75°
Occupant Compartment Deformation	No deformation greater than 6"	Specific limits of deformation based on the regions of the vehicle interior
Test Evaluation	Pass, Fail, or Marginal	Pass or Fail
Windshield Damage Criteria	Subjective/Qualitative	Objective/Quantitative
Vehicle Rebound in Crash Cushion Tests	None	Required
Exit Conditions	Subjective	Exit Box Criteria

MASH 2009 contains crash test matrices for the following:

- Longitudinal Barriers
- Terminals and Crash Cushions
- Truck and Trailer Mounted Attenuators
- Support Structures, Work-Zone Traffic Control Devices, and Breakaway Utility Poles

MASH 2009 also contains evaluation recommendations for Roadside Geometric Features and Pavement Discontinuities.

In MASH 2009 there are recommended impact performance evaluation criteria for the safety features (roadside hardware, etc.) tested. The three main factors are structural adequacy, occupant risk, and post-impact vehicular response. These three main factors have specific criteria for each.

The basic evaluation criteria for Structural Adequacy are (See MASH 2009 for more information):

- The test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable (see MASH 2009 for applicable tests).
- The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding (see MASH 2009 for applicable tests).
- Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle (see MASH 2009 for applicable tests).

The basic evaluation criteria for Occupant Risk are (See MASH 2009 for more information):

- Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone (for all tests).
- Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH 2009 (for all tests).
- Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle (see MASH 2009 for applicable tests).
- The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees (see MASH 2009 for applicable tests)
- It is preferable, although not essential, that the vehicle remain upright during and after collision. (see MASH 2009 for applicable tests).
- Longitudinal and Lateral occupant impact velocities (OIV) preferred are 30 ft/s and maximum of 40 ft/s. (see MASH 2009 for applicable tests and how to calculate OIV)
- Longitudinal occupant impact velocities (OIV) preferred are 10 ft/s and maximum of 16 ft/s (see MASH 2009 for applicable tests and how to calculate OIV).
- Longitudinal and lateral occupant ridedown acceleration limits (G) preferred are 15.0 G and a maximum of 20.49 G (see MASH 2009 for applicable tests and how to calculate occupant ridedown acceleration).

The basic evaluation criteria for post-impact vehicular response (Vehicle Trajectory) are (See MASH 2009 for more information):

- Vehicular trajectory behind the test article is acceptable (see MASH 2009 for applicable tests).

The following table is only a portion of the recommended test matrices for longitudinal barriers and is provided to aid the designer of roadside safety hardware as to which test level should be used; however, the test level guidance SDDOT follows is in other portions of Chapter 10 of the Road Design Manual along with the Appendices:

TEST LEVEL	BARRIER SECTION	TEST NO.	VEHICLE	IMPACT SPEED (mph)	IMPACT ANGLE (deg.)
1	Length-of-Need	1-10	1100C	31	25
		1-11	2270P	31	25
	Transition	1-20 ^d	1100C	31	25
		1-21	2270P	31	25
2	Length-of-Need	2-10	1100C	44	25
		2-11	2270P	44	25
	Transition	2-20 ^d	1100C	44	25
		2-21	2270P	44	25
3	Length-of-Need	3-10	1100C	62	25
		3-11	2270P	62	25
	Transition	3-20 ^d	1100C	62	25
		3-21	2270P	62	25
4	Length-of-Need	4-10	1100C	62	25
		4-11	2270P	62	25
		4-12	10000S	56	15
	Transition	4-20 ^d	1100C	62	25
		4-21	2270P	62	25
		4-22	10000S	56	15
5	Length-of-Need	5-10	1100C	62	25
		5-11	2270P	62	25
		5-12	36000V	50	15
	Transition	5-20 ^d	1100C	62	25
		5-21	2270P	62	25
		5-22	36000V	50	15
6	Length-of-Need	6-10	1100C	62	25
		6-11	2270P	62	25
		6-12	36000T	50	15
	Transition	6-20 ^d	1100C	62	25
		6-21	2270P	62	25
		6-22	36000T	50	15

d: Test is Optional

See MASH 2009 for Test Configurations, Impact Points, Acceptable IS Range, Tolerances, and Evaluation Criteria.

A new edition of MASH was published in 2016 with some additional crash testing matrices and information regarding the use of cable barrier in sloped medians. Other technical changes in this edition included:

- Testing soil strength at the crash test laboratory
- Length of tractor trailer trucks changed to use the trailer length currently manufactured (53')
- Ballasting trucks
- Method of measuring hood heights of test vehicles
- Impact severity tolerance for single unit trucks and tractor-trailers

This appendix may not be current in regard to MASH 2016 as there are Errata developed for MASH 2016 as the need arises. These "Errata" are typically developed when crash test facilities experience a special situation or vehicle models change. There could be a need for additional evaluation requirements too as the need arises.

APPENDIX C CHAPTER 10

AASHTO/FHWA JOINT IMPLEMENTATION AGREEMENT FOR THE AASHTO MANUAL FOR ASSESSING SAFETY HARDWARE (MASH), 2016 AND OTHER INFORMATION

AASHTO/FHWA Joint Implementation Agreement for the AASHTO Manual for Assessing Safety Hardware, 2016

Implementation of the 2016 edition of the AASHTO Manual for Assessing Safety Hardware (MASH) will be as follows:

- The AASHTO Technical Committee on Roadside Safety will continue to be responsible for developing and maintaining the evaluation criteria as adopted by AASHTO. FHWA will continue its role in issuing letters of eligibility of highway safety hardware for federal-aid reimbursement.
- Agencies are urged to establish a process to replace existing highway safety hardware that has not been successfully tested to NCHRP Report 350 or later criteria.
- Agencies are encouraged to upgrade existing highway safety hardware to comply with the 2016 edition of MASH either when it becomes damaged beyond repair, or when an individual agency's policies require an upgrade to the safety hardware.
- For contracts on the National Highway System with a letting date after the dates below, only safety hardware evaluated using the 2016 edition of MASH criteria will be allowed for new permanent installations and full replacements:
 - December 31, 2017: w-beam barriers and cast-in-place concrete barriers
 - June 30, 2018: w-beam terminals
 - December 31, 2018: crash cushions
 - December 31, 2019: bridge rails, cable barriers, cable barrier terminals, flared w-beam terminals, transitions, all other longitudinal barriers (including portable barriers installed permanently), all other terminals, sign supports, and all other breakaway hardware
- Temporary work zone devices, including portable barriers, manufactured after December 31, 2019, must have been successfully tested to the 2016 edition of MASH. Such devices manufactured on or before this date, and successfully tested to NCHRP Report 350 or the 2009 edition of MASH, may continue to be used throughout their normal service lives.
- Regarding the federal-aid eligibility of highway safety hardware, after December 31, 2016:
 - FHWA will no longer issue eligibility letters for highway safety hardware that has not been successfully crash tested to the 2016 edition of MASH.

- Modifications of eligible highway safety hardware must utilize criteria in the 2016 edition of MASH for re-evaluation and/or retesting.
- Non-significant modifications of eligible hardware that have a positive or inconsequential effect on safety performance may continue to be evaluated using finite element analysis.

The following link is the AASHTO Link to MASH Implementation Information:

<https://design.transportation.org/mash-implementation/>

Under the “Resources” section in the above link, the AASHTO “Clarifications on Implementing MASH 2016 (aka MASH Q & A), August 7, 2020” can be found and will need to be selected to view the MASH Q & A. A direct link to the MASH Q & A would be referenced; however, the date on the link is subject to change as to when the latest updates have been made.

The following information is from the MASH Q & A and provides some general information about the MASH Q & A:

Clarifications on Implementing the AASHTO *Manual for Assessing Safety Hardware*, 2016
Updated: August 7, 2020

The following is a compilation of all questions and answers (Q&A) that have been developed since May 2018 for the purpose of clarifying and implementing the 2016 edition of the *Manual for Assessing Safety Hardware* (MASH), which is published by the American Association of State Highway and Transportation Officials (AASHTO). The information in this document, which is updated periodically, has been approved by AASHTO and FHWA for dissemination to the roadside safety hardware community. The answers were developed by a joint technical working group of representatives from state transportation departments, the Federal Highway Administration, and accredited crash testing laboratories.

The numbers associated with each question indicate the date of publication of the Q&A. If a response has been updated since its original publication, the previous answer will be noted as “superseded.”

For answers to specific questions about the federal-aid eligibility process, please see FHWA’s [Roadside Hardware Policy Memoranda and Guidance](#). The joint implementation agreement may be viewed [here](#).

Note: On June 15, 2020, AASHTO released errata for the 2016 edition of the *Manual for Assessing Safety Hardware* (MASH). A description of these changes is located at: <http://downloads.transportation.org/MASH-2-UL-Errata.pdf>. If you previously purchased a PDF Download copy of MASH 2016 from the AASHTO Store, you may download the new version by clicking on “My Account” and “My Publications” at: <https://store.transportation.org/>.

The following is a snip of the FHWA "Roadside Hardware Policy Memoranda and Guidance" web page:

Here is a link to this site:

https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/policy_memo_guidance.cfm

The screenshot shows a web page with a blue header containing the word "Safety" and navigation links: "About", "Office of Safety Programs", "Initiatives", "Resources", and "Contact". A search bar is located on the right. Below the header, a breadcrumb trail reads "FHWA Home / Safety / Roadway Department / Roadside Hardware Policy Memoranda and Guidance". The main content area is titled "Roadside Hardware Policy Memoranda and Guidance" and features a sidebar on the left with a "PROGRAM CONTACT" box listing Will Longstreet and Menna Yassin. The main text is organized into sections: "Eligibility Process", "NTSB Recommendations", and "AASHTO Guidance", each containing a list of bullet points with links to various FHWA documents and reports.

Safety

About Office of Safety Programs Initiatives Resources Contact

FHWA Home / Safety / Roadway Department / Roadside Hardware Policy Memoranda and Guidance

Roadside Hardware Policy Memoranda and Guidance

Eligibility Process

- NEW!! Eligibility of Crash Cushion devices (Manual for Assessing Safety Hardware (MASH) 16 sunset date) – 12/20/2018** – This memorandum is to provide guidance to the FHWA Division Offices on the eligibility of National Cooperative Highway Research Program 350 (NCHRP 350) compliant crash cushions on the National Highway System (NHS) in the absence of an acceptable American Association of State Highway Transportation Officials (AASHTO) MASH 16 compliant crash cushion
- Existing Roadside Safety Hardware Eligibility Letters Affected by May 26, 2017 Memorandum** – This memo updates FHWA Division Offices on the FHWA implementation of process changes described in FHWA letter "An open letter to all in the highway safety hardware and roadside design community" dated May 26, 2017.
- Evaluating a State DOT's Process to Determine Roadside Safety Hardware Crashworthiness on the National Highway System (NHS)** – April 9, 2018. This memo provides guidance to FHWA Division Offices to assist their evaluation that a State DOT has an acceptable process for determining crashworthiness of roadside safety hardware on the NHS
- An open letter to all in the highway safety hardware and roadside design community** – May 26, 2017. This letter informs of important changes to the Federal-aid eligibility process.
- Federal-aid Reimbursement Eligibility Process for Safety Hardware Devices** – November 12, 2015. This memo informs of important changes to the Federal-aid eligibility process
- An open letter to all in the highway safety hardware and roadside design community** – November 12, 2015. This letter notifies of additional improvements in the process since the May 18 letter on this topic.
- An open letter to all in the highway safety hardware and roadside design community - May 18, 2015** . This letter details FHWA's revised process for issuing Federal-aid eligibility letters for roadside safety hardware systems.
- In-service Performance Evaluation and Continuous Monitoring** – November 17, 2005. The memorandum recommends that states monitor the performance of crashworthy roadside safety hardware to assess field performance, considering installation conditions and maintenance history among other factors, by referring to [NCHRP Report 480^o In Service Performance of Traffic Barriers^o](#)

NTSB Recommendations

- ACTION: State Guidelines for Cable Median Barriers** – April 25, 2016. This memo clarifies cable barrier crash test criteria in the AASHTO MASH to address recommendation H-15-41 from the NTSB.
- ACTION: Median Barriers on Divided Highways Regardless of Access Type** – July 9 2014. Recommendation from the National Transportation Safety Board regarding median barriers on divided highways with less than full control of access.
- Information Memorandum regarding NCHRP Report 711** – November 27, 2012. This memo refers practitioners to NCHRP Report 711: Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems.
- Commercial Passenger Vehicle Crashes Involving Roadside Point Hazards** – October 4, 2012. Information concerning the safety issues associated with commercial passenger vehicle (CPV) crashes involving roadside point hazards and the use of high performance level barriers to address the safety issues, by referring to [NCHRP Report 638: Guidelines for Guardrail Implementation](#). Report 638 gives specific guidelines for the application of guardrail and guardrail terminals.

AASHTO Guidance

- Change to the December 31, 2018 sunset date in the AASHTO/FHWA Joint Implementation Agreement for the AASHTO MASH** – The purpose of this memo is to announce exceptions to the December 31, 2018 sunset date for cable barriers and cable barrier terminals.
- Change to the June 30, 2018 sunset date in the AASHTO/FHWA Joint Implementation Agreement for the AASHTO MASH** – The purpose of this memo is to announce exceptions to the June 30, 2018 sunset date for w-beam terminals
- Clarification on Implementing the AASHTO MASH** – The purpose of this memo is to provide clarification on technical and implementation issues pertaining to AASHTO MASH
- Clarification of Roles and Responsibilities in Implementing the AASHTO/FHWA Joint Implementation Agreement on the AASHTO MASH** – March 17, 2017. Describes the different roles and responsibilities since the transition from NCHRP Report 350 to AASHTO's MASH criteria
- AASHTO/FHWA Joint Implementation Agreement for Manual for Assessing Safety Hardware (MASH)** – January 7, 2016. This memo provides key information on roles and dates in the agreement.
- AASHTO Roadside Design Guide 4th Edition** – June 26, 2012. The purpose of this memo is three-fold: reiterate the status of the RDG for FHWA, summarize significant changes in the RDG 4th edition, and add Frequently Asked Questions to our website.

Barrier and Terminal Design and Installation

- [ACTION: Guardrail Terminal Installations and Repairs](#) – November 30, 2016. Brings attention to guardrail terminal installation and repair issues.
- [ACTION: REACT 350 Crash Cushion](#) – September 14, 2016.
- [ACTION: Roadside Safety Hardware – May 26 2015](#). Installation and maintenance of guardrail terminals.
- [ACTION: ET-Plus W-Beam Guardrail Terminal Memorandum](#) – October 10, 2014. Advises on recent developments, ongoing activity, action, and request for information.
- [ET-Plus W-Beam Guardrail Terminal Memorandum](#) – June 17, 2014. Provides information on eligibility of the device for Federal-aid reimbursement.
- [ACTION: Application and Installation of Roadside Hardware](#) – November 3, 2010. This memorandum addresses the proper application and installation of roadside safety hardware, and supersedes the memorandum of the same subject dated October 1, 2010
- [ACTION: Roadside Design: Steel Strong Post W-beam Guardrail](#) – May 17, 2010. Provides guidance on the height of guardrail for new installations on the National Highway System.
- [ACTION: Supplementary Guidance for the Selection of W-Beam Barrier Terminals](#) – November 17, 2005. This memorandum supplements the October 26, 2004 memorandum on the same topic, and provides additional information to assist designers in making appropriate barrier terminal selections.
- [Guidelines for the Selection of W-Beam Barrier Terminals](#) – October 26, 2004. The purpose of this memorandum is to provide specific information on the characteristics of most W-beam guardrail terminals that have been accepted for use on the NHS under the test evaluation criteria contained in NCHRP Report 350, and to provide guidelines for their selection.
- [Bridge Rail Analysis](#) – May 16, 2000. Information and example of analysis for bridge railings that are essentially the same as crash-tested designs.
- [Technical Advisory T5040](#) – April 13, 1992 – [Curved W-Beam Guardrail Installations at Minor Roadway Intersection](#)
 - [Drawings](#)
 - [Eligibility Letter B-209](#)

Archive

- [Roadside Safety Hardware-Federal-Aid Reimbursement Eligibility Process](#) – May 21, 2012 **SUPERSEDED**
[Note: This memo has been superseded. Updated information was provided in a [November 12, 2015 memo](#).]
- [Information Memorandum: Cable Barrier Considerations](#) – July 20, 2007
[Note: Much of the information in the memo was superseded by the research found in [NCHRP Report 711](#).]
- [Guidelines for the Selection of Crash Cushions](#) – January 3, 2000 [PDF, 841 KB] **CANCELED**
[Note: This memo has been cancelled. See the [AASHTO Roadside Design Guide](#) for current information.]
- [Action Memorandum: National Cooperative Highway Research Program \(NCHRP\) Report 350 Hardware Compliance Dates](#) – August 28, 1998
- [Information Memorandum: Crash Tested Work Zone Traffic Control Devices](#) – August 28, 1998 [PDF, 3.73 MB]
- [ACTION: Crash Testing of Bridge Railings](#) – May 30, 1997
- [ACTION: Identifying Acceptable Highway Safety Features](#) – July 25, 1997. **SUPERSEDED**
[Note: This memo has been superseded. Updated information can be found in a [November 12, 2015 memo](#).]
- [ACTION: Traffic Barrier Safety Policy and Guidance](#) – September 29, 1994 [PDF, 1.06 MB]
[Note: Some of the information in this memo was superseded in [August 1998](#) and later memos.]
- [Technical Advisory 5040.34, – Guardrail Transitions](#) June 8, 1993 **SUPERSEDED**
[Note: This memo was superseded by implementation of NCHRP Report 350 as indicated in an [August 1998 memo](#).]
- [Corrugated Steel Guardrail Terminals](#) – February 9, 1993 [PDF, 4.60 MB] **CANCELED**
- [Performance of Guardrail Curb Combinations](#) – February 28, 1992 [PDF, 267 KB]
[Note: This memo has been cancelled. See the [NCHRP Report 537 – Recommended Guidelines for Curb and Curb-Barrier Installations](#).]
- [Breakaway Sign and Luminaire Supports](#)– July 6, 1990 [PDF, 567 KB] **SUPERSEDED**
- *[Note: This memo was superseded by implementation of NCHRP Report 350 as indicated in an [August 1997 memo](#).]*
- [W-Beam Guard Rail End Terminals](#) – June 28, 1990 [PDF, 848 KB] **SUPERSEDED**
[Note: This memo was superseded in [September, 1994](#).]
- [Determination of Strengthened Guardrail Deflection](#) – May 18 1989 [PDF, 3.34 MB] **CANCELED**
[Note: This memo has been cancelled. See the [AASHTO Roadside Design Guide](#) for current information.]
- [Technical Advisory 5040.26, January 28, 1988 – Guardrail Transitions](#) **SUPERSEDED**
[Note: This memo was superseded by implementation of NCHRP Report 350 as indicated in an [August 1998 memo](#).]

Page last modified on December 21, 2018



APPENDIX D CHAPTER 10

SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION PROCESS FOR DETERMINING CRASHWORTHINESS OF ROADSIDE SAFETY HARDWARE USED ON THE NATIONAL HIGHWAY SYSTEM

In conjunction with the AASHTO/FHWA Joint Implementation Agreement for the AASHTO Manual for Assessing Safety Hardware (MASH), the South Dakota Department of Transportation (SDDOT) will determine crashworthiness of roadside safety hardware used on the National Highway System (NHS). If SDDOT determines safety hardware is crashworthy and meets SDDOT's needs, the hardware will be approved for use on NHS projects. To determine if the hardware meets SDDOT's needs, SDDOT will consider factors including but not limited to ease of installation, maintenance requirements, cost, materials, in-service performance, and appropriateness for South Dakota climate.

If SDDOT has determined a product or system is crashworthy and meets SDDOT's needs, SDDOT will use good faith efforts to develop design guidance and standards so that the hardware may be integrated into construction plans. Until the guidance and standards are complete, the product or system will not be used on NHS projects.

Until acceptable equivalent hardware is available and deemed crashworthy by SDDOT, SDDOT will consider safety hardware that complies with the National Cooperative Highway Research Program (NCHRP) Report 350 to be crashworthy.

SDDOT's process for determining crashworthiness of roadside safety hardware is as follows:

Procedures for Proprietary Hardware:

1. SDDOT will determine if Federal Highway Administration (FHWA) has issued a federal-aid reimbursement eligibility letter for the proprietary hardware. Although an FHWA federal-aid reimbursement eligibility letter is desired and will be given consideration in SDDOT's crashworthiness determination, it is not a requirement.
2. Proprietary hardware must be tested at an accredited crash test laboratory that is independent of the manufacturer. The laboratory must identify and perform the tests necessary to demonstrate crashworthiness and must generate a report of test results.

3. All pertinent crash test videos, crash test reports, in-service performance records, detailed drawings, installation guidelines, specific use requirements, and specifications must be provided to SDDOT. Any efforts to receive a federal-aid reimbursement eligibility letter from FHWA must be summarized within the submittal to SDDOT. The submittal must include the manufacturer's certification that the hardware is crashworthy.
4. SDDOT will review the submitted information and determine whether the hardware complies with crashworthy requirements.
5. If SDDOT determines the hardware is crashworthy and meets SDDOT's needs, the hardware may be used on the NHS.
6. If SDDOT determines the hardware is crashworthy and meets SDDOT's needs, but a federal-aid reimbursement eligibility letter has not been issued by FHWA, SDDOT will request concurrence in the approval of the proprietary hardware for use on the NHS from the FHWA division administrator. FHWA concurrence is not required for SDDOT to use the hardware on the NHS.
7. SDDOT will monitor the performance of the hardware through review of crash reports and other information.
8. At any time, SDDOT may determine that the hardware will no longer be installed on the NHS.

Procedures for Modifications to Proprietary Hardware Previously Approved for Use on NHS:

1. If SDDOT has approved proprietary hardware for use on the NHS and the hardware is subsequently modified, the hardware may not be used on the NHS until SDDOT and the manufacturer completes the process set out in this section.
2. The manufacturer will provide SDDOT with an analysis from an accredited crash test laboratory that is independent of the manufacturer. The analysis will address whether the modification will affect the hardware's performance and whether any additional testing or evaluation is needed.
3. If the crash test laboratory recommends additional testing or evaluation, then the manufacturer will provide the complete test or evaluation results to SDDOT.
4. SDDOT will review the information and determine whether the hardware is crashworthy and meets SDDOT's needs.
5. If SDDOT determines the hardware is crashworthy and meets SDDOT's needs, but a federal-aid reimbursement eligibility letter has not been issued by FHWA, SDDOT will request concurrence in the approval of the hardware for use on the NHS from the FHWA division administrator. FHWA concurrence is not required for SDDOT to use the hardware on the NHS.

6. SDDOT will monitor the performance of the hardware through review of crash reports and other information.
7. At any time, SDDOT may determine that the hardware will no longer be installed on the NHS.

Procedures for Non-Proprietary Hardware:

1. SDDOT will determine if FHWA has issued a federal-aid reimbursement eligibility letter for the hardware. Although an FHWA federal-aid reimbursement eligibility letter is desired and will be given consideration in SDDOT's crashworthiness determination, it is not a requirement.
2. SDDOT will obtain and review reports and other documentation relating to whether the non-proprietary hardware is crashworthy.
3. If SDDOT determines the hardware is crashworthy, SDDOT will consider additional factors to determine if the hardware meets SDDOT's needs. The hardware may be used on the NHS if SDDOT determines the hardware meets SDDOT's needs.
4. If SDDOT determines the non-proprietary hardware is crashworthy and meets SDDOT's needs, the hardware will be shown on SDDOT's standard plates and will be included in SDDOT's standard specifications, where appropriate.
5. If SDDOT determines the hardware is crashworthy and meets SDDOT's needs, but a federal-aid reimbursement eligibility letter has not been issued by FHWA, SDDOT will request concurrence in the approval of the hardware for use on the NHS from the FHWA division administrator. FHWA concurrence is not required for SDDOT to use the hardware on the NHS.
6. SDDOT will monitor the performance of the hardware through review of crash reports and other information.
7. At any time, SDDOT may determine that the hardware will no longer be installed on the NHS.

In-Service Performance:

In rare circumstances, as an alternative to any of the procedures identified above, SDDOT may determine crashworthiness based on in-service performance. In-service performance evaluation will be conducted through pooled fund studies or other research projects, or in accordance with NCHRP Report 490.