CHAPTER 10

ROADSIDE SAFETY

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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*.

**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), 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).

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 and return to the roadway 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 shall be reviewed and evaluated for other fixed objects within the highway right-of-way (ROW) area. This evaluation shall 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, breakaway-type luminaire poles, and 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.

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, consider using 80 foot offset to determine guardrail length. See Barrier Design Step 7. c.) Median Design.
  - For Interstate medians, a 40 foot clear zone should be used at bridge columns/piers locations.

- for intermediate speed (45 to 50 mph Design Speed) projects with or without curb and gutter engineering judgment shall 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 ADT, 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.

- for low speed (< 40 mph Design Speed) projects with or without curb and gutter lateral offset will be utilized in place of clear zone. See the section regarding lateral offset guidance on page 10-9.

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 10-2 are used for determining clear zone:
Table 10-1 Clear Zone for 3R Projects on National Highway System

<table>
<thead>
<tr>
<th>Existing Traffic Volume (Total ADT)</th>
<th>Clear Zone (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 551</td>
<td>10</td>
</tr>
<tr>
<td>551 to 1500</td>
<td>15</td>
</tr>
<tr>
<td>1501 to 2500</td>
<td>20</td>
</tr>
<tr>
<td>&gt; 2500</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 10-2 Clear Zone for 3R Projects Other Than National Highway System

<table>
<thead>
<tr>
<th>Existing Traffic Volume (Total ADT)</th>
<th>Clear Zone (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 551</td>
<td>10</td>
</tr>
<tr>
<td>551 to 1500</td>
<td>15</td>
</tr>
<tr>
<td>&gt; 1500</td>
<td>20</td>
</tr>
</tbody>
</table>

- for intermediate speed (45 to 50 mph Design Speed) projects with or without curb and gutter, engineering judgment shall 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 10-2 for the same ADT.

- for scenic or recreational routes (≤ 40 mph Design Speed) a minimum clear zone of 4 feet should be considered.

- for low speed (≤ 40 mph Design Speed) projects with or without curb and gutter lateral offset will be utilized in place of clear zone. See the section regarding lateral offset guidance.
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.

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 provide the 5 foot lateral offset to obstructions at intersections and driveways for sight distance and off-tracking trucks. See Chapter 12 of the Road Design Manual for information regarding sight triangles.

More information about urban roadside design may be found in Chapter 10 of the current AASHTO publication of the Roadside Design Guide.
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 run-out 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 fills 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.

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 the 2R projects based on the current AASHTO publication of the *Roadside Design Guide*.

**Figure 10-3** Inslope Flattening
For 3R projects the following are guidelines in regards to slope flattening and protecting inslopes (ADT is existing traffic volume):

- ADT ≤ 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.

- ADT > 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.

**DITCH BOTTOM**

For more detail on ditch bottoms refer to RDM Chapter 7 – Cross Sections. See Chapter 3 of the current AASHTO publication of the *Roadside Design Guide*, Figures 3-6 and 3-7.
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 shall 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)

<table>
<thead>
<tr>
<th>Relation to Clear Zone¹</th>
<th>Cross Pipe Size</th>
<th>Type of End Treatment on Cross Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside or Outside</td>
<td>24&quot; and 30&quot;</td>
<td>Sloped End without Protective Bars</td>
</tr>
<tr>
<td>Inside</td>
<td>36&quot; and Larger Pipe, All RCBC, and All Cattle Passes</td>
<td>Not allowed inside clear zone unless barrier protection is deemed justifiable or ends have protective bars</td>
</tr>
<tr>
<td>Outside ONLY</td>
<td>36&quot; through 60&quot;</td>
<td>Flared End²</td>
</tr>
<tr>
<td>Outside ONLY</td>
<td>60&quot; and Larger, All RCBC, and All Cattle Passes</td>
<td>Flared End, Sectional Apron, or Wing Wall depending on structure²</td>
</tr>
</tbody>
</table>

¹ Refer to section on clear zone in this chapter.

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)

<table>
<thead>
<tr>
<th>Relation to Clear Zone¹</th>
<th>Cross Pipe Size</th>
<th>Type of End Treatment on Cross Pipe³</th>
<th>ADT²</th>
<th>Inslope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside and Outside</td>
<td>24” and 30”</td>
<td>Existing remain in place</td>
<td>&lt;1000</td>
<td>3:1 or Flatter</td>
</tr>
<tr>
<td>Inside</td>
<td>24” and 30”</td>
<td>Sloped End without Protective Bars</td>
<td>&gt;1000</td>
<td>3:1 or Flatter</td>
</tr>
<tr>
<td>Outside</td>
<td>24” and 30”</td>
<td>Existing remain in place</td>
<td>&gt;1000</td>
<td>3:1 or Flatter</td>
</tr>
<tr>
<td>Inside</td>
<td>36” and Larger Pipe, All RCBC, and All Cattle Passes</td>
<td>Object markers only</td>
<td>&lt;1000</td>
<td>3:1 or Flatter</td>
</tr>
<tr>
<td>Inside⁴</td>
<td>36” through 60”</td>
<td>Sloped End with Protective Bars (Consider extension to Clear Zone and consider Flared End)</td>
<td>&gt;1000</td>
<td>3:1 or Flatter</td>
</tr>
<tr>
<td>Inside⁴</td>
<td>Larger than 60”, All RCBC, and All Cattle Passes</td>
<td>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 barrier⁵</td>
<td>&gt;1000</td>
<td>3:1 or Flatter</td>
</tr>
<tr>
<td>Outside</td>
<td>Larger than 60”, All RCBC, and All Cattle Passes</td>
<td>Existing remain in place</td>
<td>&gt;1000</td>
<td>3:1 or Flatter</td>
</tr>
</tbody>
</table>

¹ Refer to section on clear zone in this chapter.
² ADT is current ADT.
³ See Standard Plate 632.10 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.
Table 10-5  Approach Treatment for Construction/Reconstruction (Non-Interstate)

<table>
<thead>
<tr>
<th>Relation to Clear Zone</th>
<th>Approach Pipe Size</th>
<th>Type of End Treatment on Approach Pipe</th>
<th>Approach Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside</td>
<td>18” and 24”</td>
<td>Safety End <strong>without</strong> Protective Bars</td>
<td>6:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For multiple pipe installations, protective bars may be considered.</td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>18” and 24”</td>
<td>Safety End <strong>without</strong> Protective Bars</td>
<td>6:1&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inside</td>
<td>30” through 60”</td>
<td>Safety End <strong>with</strong> Protective Bars</td>
<td>6:1</td>
</tr>
<tr>
<td>Outside</td>
<td>30” through 36”</td>
<td>Safety End <strong>without</strong> Protective Bars</td>
<td>6:1&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protective bars may be provided where deemed appropriate.</td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>42” through 60”</td>
<td>Safety End <strong>with</strong> Protective Bars</td>
<td>6:1&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flared ends may be considered if there is measurable cost savings.</td>
<td></td>
</tr>
<tr>
<td>Outside ONLY</td>
<td>Larger than 60”</td>
<td>Flared Ends shall be considered or consider smaller multiple pipe and end sections.</td>
<td>6:1&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> See section on clear zone in this chapter.

<sup>2</sup> 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.

<sup>3</sup> Protective Bars to be provided for structural reasons.
Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates.


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

<table>
<thead>
<tr>
<th>Relation to Clear Zone&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Approach Pipe Size</th>
<th>Type of End Treatment on Approach Pipe</th>
<th>ADT&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Approach Slope&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside or Outside</td>
<td>18&quot; and 24&quot;</td>
<td>Flared Ends may remain in place</td>
<td>&gt;500</td>
<td>6:1&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inside</td>
<td>30&quot; and Larger</td>
<td>Consider SAFETY ENDS with bars</td>
<td>&gt;500</td>
<td>6:1&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Outside ONLY</td>
<td>30&quot; and Larger</td>
<td>Flared Ends may remain in place</td>
<td>&gt;500</td>
<td>6:1&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inside or Outside</td>
<td>All Sizes</td>
<td>Flared Ends may remain in place</td>
<td>≤500</td>
<td>6:1&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Refer to section on clear zone in this chapter.

<sup>2</sup> ADT is current ADT.

<sup>3</sup> As measured within the clear zone.

<sup>4</sup> Approach slope should be previously flattened to 6:1 or flatter.

<sup>5</sup> Approach or ditch block slope flattening may not be necessary. Design exception should be approved.
Table 10-7  Pipe Culvert Treatment on Interstate Projects

<table>
<thead>
<tr>
<th>Location of End Section</th>
<th>Relation to Clear Zone&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Cross Pipe Size</th>
<th>Type of End Treatment on Cross Pipe</th>
<th>Inslope&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDIAN INSLOPES</td>
<td>Inside</td>
<td>18” to 30”</td>
<td>Sloped End without Protective Bars</td>
<td>5:1</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>18” to 30”</td>
<td>Safety End without Protective Bars</td>
<td>6:1</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>36” and Larger</td>
<td>Sloped End with Protective Bars</td>
<td>5:1</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>36” and Larger</td>
<td>Safety End with Protective Bars</td>
<td>6:1</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>All Sizes</td>
<td>FLARED ENDS may remain in place</td>
<td>NA</td>
</tr>
<tr>
<td>OUTSIDE INSLOPES</td>
<td>Inside</td>
<td>18” and 24”</td>
<td>Sloped End without Protective Bars</td>
<td>4:1 or 5:1</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>18” and 24”</td>
<td>Safety End without Protective Bars</td>
<td>6:1</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>30”</td>
<td>Sloped End without Protective Bars</td>
<td>4:1, 5:1, or 6:1</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>36” and Larger</td>
<td>Sloped End with Protective Bars</td>
<td>4:1, 5:1, or 6:1</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>All Sizes</td>
<td>FLARED ENDS may remain in place</td>
<td>NA</td>
</tr>
<tr>
<td>Location of End Section</td>
<td>Relation to Clear Zone&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Crossover Pipe Size</td>
<td>Type of End Treatment on Crossover Pipe</td>
<td>Transverse Slope&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crossover Transverse SLOPES</td>
<td>Inside</td>
<td>18” and Larger</td>
<td>Safety End with Protective Bars</td>
<td>6:1</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>18” and Larger</td>
<td>Safety End without Protective Bars</td>
<td>6:1</td>
</tr>
</tbody>
</table>

<sup>1</sup> Refer to section on clear zone in this chapter.

<sup>2</sup> As measured within the clear zone.
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 drop inlets are used, the drop inlets should be placed as far away from the bridge as practical (near the end of the approach slabs) between the required guardrail post spacing.

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:

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

  W Beam Guardrail may be used only if it is Double Class A W Beam Guardrail with Wood Posts (post spacing would remain at 6’-3”) and the only curb type allowed is Type D Curb and Gutter.

  Only W Beam guardrail tangent end terminals will be used in areas with adjacent curb and gutter and posted speed limit greater than 40 mph. P gutter shall be used 37.5 feet prior to the W beam guardrail tangent end terminal and end at the beginning of the W beam guardrail as shown in Figure 10-5.

![Figure 10-5 Guardrail adjacent to Curb and Gutter: Posted Speed Greater than 40 mph](http://www.sddot.com/business/design/news/default.aspx)
• Posted speed limit 40 mph

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

W Beam Guardrail may be Single Class A W Beam Guardrail with Wood Posts (post spacing would remain at 6’-3”) and can be used adjacent to all types of curb and gutter (Type B, D, F, and P gutter).

With posted speed of 40 mph and W Beam Guardrail is installed adjacent to curb and gutter, modification of curb and gutter is not required at end terminals and a tangent end terminal shall be installed. See Figure 10-6.

Figure 10-6  Guardrail adjacent to Curb and Gutter: Posted Speed 40 mph
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, it is recommended that median barriers be considered for high speed (≥ 55 mph) highways with a median width of 30 feet or less (measured from edge of traveled way to edge of traveled way) and the Design ADT is greater than 20,000 as shown in Figure 10-7.

To determine if a median barrier is warranted a study should be performed which may include a cost/benefit analysis and/or crash review for the follow types of projects:
- Median width is 30 feet or less and the Design ADT 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 normally considered except in special circumstances such as a location with a significant history of cross median crashes.

A typical median barrier SDDOT uses is a double faced 32 inch tall Jersey shaped reinforced concrete barrier. If necessary, glare screens may be provided on top of the concrete barrier.

![Median Barrier Warrants](image)

* Based on a 6-year projection

**Figure 10-7** Median Barrier Warrants
A barrier or guardrail is a device which 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:

- Jersey safety shape (32 inch height) concrete barrier
- Steel beam guardrail (Thrie Beam and W Beam)
- Cable guardrail (South Dakota standard is Three Cable Guardrail)

Each type of barrier has different characteristics; however, all barriers must terminate with an approved crashworthy terminal that meets Test Level 3 (TL-3) crash test requirements of National Cooperative Highway Research Program (NCHRP) 350 at a minimum or Test Level 3 (TL-3) crash test requirements of Manual for Assessing Safety Hardware (MASH).

Upgrades to safety hardware that meets NCHRP 350 TL-3 at a minimum shall be considered on the following types of projects. The designer should look at the existing condition (use HR54Guardrail program and Guardrail Inspection and Maintenance Guidance) of the barriers and end terminals and verify that the condition is within the maintenance standards at a minimum. If there is a decision to not upgrade the barrier to the requirements of NCHRP 350 TL-3 when there are available NCHRP 350 TL-3 devices, then a design exception shall be provided. A designer may choose not to upgrade the barrier if there is a subsequent project in the current approved STIP.

- Resurfacing (asphalt and concrete overlays, new asphalt surface, new concrete surface, resurfacing interstate shoulders, etc.)
- Reconstruction
- Bridge Deck Overlays where the bridge rail is being modified
- Rehabilitation Projects (slope flattening, shoulder widening, etc.)

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

- Pavement Preservation
- Bridge Deck Overlays where the bridge rail is not being modified and minimal (See Table 10-9 Height to Top of Barrier) or no approach work is to be done.
- General Roadway Maintenance (joint route and seal, etc.)
Concrete Barriers

The Jersey safety shape (32” height) concrete barrier is the typical rigid barrier system used in South Dakota.

The Jersey safety shape (32” height) concrete barrier is used on structures where no deflection is allowed and 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. This barrier meets the crash test requirements of NCHRP 350 TL-4.

The Jersey safety shape 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 Jersey safety shape reinforced concrete barrier.

Taller double faced Jersey safety shape barriers have been used in median locations where traffic counts are higher and past crash history involving cross median and crashes in medians have shown higher rates. The taller barriers provide extra safety due to its ability to act as a glare screen too. 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 Chapter 6 of the current AASHTO publication of Roadside Design Guide and in this chapter under “Medians”.

In urban areas or projects in the Black Hills where the design speed is less than 45 mph, there needs to be a more maintenance friendly barrier due to higher crash frequency, and sight distance is an issue, there is a NCHRP 350 TL-2 low profile concrete barrier available. 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.

The following is a list of some of the concrete barriers and the NCHRP 350 test level associated with the barrier:

- Jersey Shape (32” height)   TL-4
- Jersey Shape (42” height)   TL-5
- F Shape (32” height)       TL-4
- F Shape (42” height)       TL-5
- Single Slope (32” height)  TL-4
- Single Slope (42” height)  TL-5
- Vertical Wall (32” height) TL-4
- Vertical Wall (42” height) TL-5

Where aesthetics is a concern on context sensitive projects, the designer may elect to provide an approved Stone Masonry Wall Barrier. A less costly option to provide aesthetics to a concrete barrier is to include color in the concrete. 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 facilities.

**Steel Beam Guardrail (Thrie Beam and W Beam)**

Thrie Beam Guardrail and W Beam Guardrail are standard semi-rigid barrier systems used in South Dakota.

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 a 10:1.

PI’s (point where steel rail begins to flare) shall only be located in the center portion of a section of rail.

It is preferred to use 3.5 feet of embankment for W Beam Guardrail; however, where there is limited ROW, the following may be used:

For higher speeds (45mph and greater) W Beam Guardrail may be used with the center of the wood posts placed at the breakpoint of a 2:1 slope. The W Beam Guardrail would require 7 foot long wood posts with standard blockouts and the post spacing required is 3'-1 ½". The W Beam rail required is Class A.

For slower speeds (40mph and less) W Beam Guardrail may be used with the center of the wood posts placed at the breakpoint of a 2:1 slope. The W Beam Guardrail would require 7 foot long wood posts with standard blockouts and the post spacing required is 6'-3". The W Beam rail required is Class A.

Where aesthetics is a concern on context sensitive projects, the designer may elect to provide an AASHTO Type 4 rail (i.e. cortan/weathering steel). However; this type of guardrail 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.

Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates.  
Three Cable Guardrail is the standard flexible barrier system used in South Dakota.

A primary advantage cable guardrail has over the other types of barrier installations is that its open design reduces snow drifting problems on or alongside the roadway.

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. Consequently 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 in order to function properly.

Cable guardrail shall not be placed on slopes steeper than a 10:1, shall not be installed where the approach slope is steeper than a 10:1, and shall 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 standard 3 cable guardrail. The special design consists of post spacing of 4 feet and a berm (platform) of at least 4 feet wide behind the cable guardrail. The berm slope shall match the roadway cross slope or no steeper than a 10:1. The posts shall only be the S3x5.7 steel posts with soil plates and 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 W Beam Guardrail placed at the breakpoint of the slope as 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 option is to place a high tension cable guardrail with 2 feet of embankment. Refer to the next section regarding High Tension Cable Guardrail.

High Tension Cable Guardrail

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

Although the 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 where there is not enough room for extra embankment or when the deflection requirements would require using high tension cable guardrail instead of standard 3 cable guardrail.

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

Bridge columns or other obstacles on the Interstates should be protected with high tension cable guardrail if the cable guardrail is stand-alone (not attached and transitioned into W beam) and the obstacle is 8 feet and greater from the high tension cable guardrail. If it is not possible to construct a 2 foot embankment, we have installed a NCHRP 350 TL-4 high tension cable guardrail 4 feet laterally from the slope breakpoint on a 6:1 slope as this installation would make the TL-4 system (this is a 4 cable system) a NCHRP 350 TL-3 installation.

See Section B – Grading plan notes for plan notes regarding high tension cable guardrail as the notes contain information regarding design and plans information.
When barrier is warranted, the selection of a barrier system should be based on the one that offers the required degree of shielding at the lowest cost for the specific application. Refer to Chapter 5 of the current AASHTO publication of the *Roadside Design Guide* for further selection guidelines for use of a roadside barrier.

Table 10-8 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 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. It is recommended that the design deflection be maintained 25 feet at a minimum upstream of a rigid obstacle being protected for semi-rigid barriers (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”.

<table>
<thead>
<tr>
<th>Barrier Type</th>
<th>Post Spacing</th>
<th>Maximum Design Deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Barrier</td>
<td>NA</td>
<td>0’</td>
</tr>
<tr>
<td>Double Thrie Beam</td>
<td>3’-1 ½”</td>
<td>0’-9”</td>
</tr>
<tr>
<td>Guardrail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrie Beam Guardrail</td>
<td>3’-1 ½”</td>
<td>1’-9”</td>
</tr>
<tr>
<td></td>
<td>6’-3”</td>
<td>2’-6”</td>
</tr>
<tr>
<td>Semi-Rigid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double W Beam</td>
<td>6’-3”</td>
<td>3’-0”</td>
</tr>
<tr>
<td>Guardrail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W Beam Guardrail</td>
<td>1’-6 ¾”</td>
<td>3’-3”</td>
</tr>
<tr>
<td></td>
<td>3’-1 ½”</td>
<td>3’-9”</td>
</tr>
<tr>
<td></td>
<td>6’-3”</td>
<td>5’-0”</td>
</tr>
<tr>
<td>Flexible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three Cable Guardrail</td>
<td>4’-0”</td>
<td>10’-6”</td>
</tr>
<tr>
<td></td>
<td>8’-0”</td>
<td>11’-6”</td>
</tr>
<tr>
<td></td>
<td>12’-0”</td>
<td>13’-0”</td>
</tr>
<tr>
<td></td>
<td>16’-0”</td>
<td>15’-0”</td>
</tr>
<tr>
<td>High Tension</td>
<td>Varies,</td>
<td>8’-0”</td>
</tr>
<tr>
<td>Cable Guardrail</td>
<td>Maximum Allowed is 16’</td>
<td></td>
</tr>
</tbody>
</table>

Table 10-9 provides height criteria for the various types of barrier.

**Table 10-9  Height to Top of Barrier**

<table>
<thead>
<tr>
<th>Barrier Type</th>
<th>Standard Height</th>
<th>Allowable Height Variances for 3R Projects&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jersey Shape Concrete Barrier&lt;sup&gt;2&lt;/sup&gt;</td>
<td>32”</td>
<td>-3” Variable&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Thrie Beam</td>
<td>32”</td>
<td>-2” +2”</td>
</tr>
<tr>
<td>W Beam</td>
<td>28”</td>
<td>-1/4” +1 1/2”</td>
</tr>
<tr>
<td>Three Cable</td>
<td>28”</td>
<td>-1/4” +1 1/2”</td>
</tr>
<tr>
<td>High Tension Cable</td>
<td>Varies with Manufacturer</td>
<td>-1” +1”</td>
</tr>
</tbody>
</table>

<sup>1</sup> The symbols “-” implies a lower elevation than standard height and “+” implies a higher elevation than standard height.

<sup>2</sup> The 32” Jersey Shape Concrete Barrier has typically been 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* Chapter 6 for more information regarding Concrete Barriers.

<sup>3</sup> See the current AASHTO publication of the *Roadside Design Guide* Chapter 6 for more information regarding Height Variance.
BARRIER TRANSITIONS

Various types of transitions are used based on the type of barrier installed. 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 section occurs between the approach barrier and bridge rail ends.

The types of transitions used in South Dakota are as follows:

- * Concrete Bridge Rail to Thrie Beam Guardrail to be used on Construction/Reconstruction projects.
- Bridge Rail to W Beam Guardrail - uses rubrail (This transition may be used on 3R projects only. Interstate structures must be upgraded to accept Thrie Beam Guardrail.)
- Thrie Beam Guardrail to W Beam Guardrail
- * W Beam Guardrail to Three Cable Guardrail - 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.
- * Transitions that have been crash tested to Test Level 3 requirements of NCHRP 350.

BARRIER END TERMINALS

On high speed roadways the barriers should terminate with an approved crashworthy terminal that meets Test Level 3 (TL-3) crash test requirements of NCHRP 350 at a minimum or MASH (TL-3).

A terminal can be either gating or non-gating. A gating terminal is designed to allow controlled penetration of a vehicle when impacted upstream of the beginning of the length of need. Regarding design, there is a distance between the end of a gating device and the beginning of the length of need of the device.
Concrete Barrier End Terminals

The approach end of concrete barrier will be transitioned to a non-gating Crash Cushion/Attenuator except in low speed projects of 35 mph or less where a Tapered Concrete Barrier will be provided.

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 crash cushion/attenuator is typically anchored to a minimum of a 8 inch thick concrete pad. The cross-slope of the pad should be level and the longitudinal grade shall 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. It is preferable to not install crash cushions on top of curbs, but the following is allowable.

- 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 shall 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. An NCHRP 350 TL-2 crash cushion is acceptable at a minimum or a MASH TL-2 crash cushion is also acceptable.

- Posted speed limit greater than 40 mph

The crash cushion may be placed adjacent to P 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. An NCHRP 350 TL-3 crash cushion is acceptable at a minimum or a MASH TL-3 crash cushion is also acceptable.
Thrie Beam Guardrail End Terminals

The approach end of Thrie Beam Guardrail will typically be transitioned to W Beam guardrail before termination.

The off-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 divided roadways where traffic only travels in one direction.

W Beam Guardrail End Terminals

For end terminals where traffic approaches the guardrail: refer to the approved products list for end terminals used in the State of South Dakota. The effective length varies depending on the type of terminal used. The designer shall specify in the plans which end terminal (Flared or Tangent) shall be constructed.

W Beam Guardrail Flared End Terminals (Figure 10-8) should assume 25 feet of the guardrail (tangent to the roadway) is available as part of the effective length of rail when computing guardrail length calculations.

![Figure 10-8 W Beam Guardrail Flared End Terminal](Image)

W Beam Guardrail Tangent End Terminals (Figure 10-9) should assume 37.5 feet of the guardrail (tangent to the roadway) is available as part of the effective length of rail when computing guardrail length calculations.

![Figure 10-9 W Beam Guardrail Tangent End Terminal](Image)

When choosing which W Beam Guardrail End Terminal to use, consider flaring the guardrail based on the following:

- Crash History (If there are higher number of crashes then consider flaring the guardrail away from the roadway. The further guardrail is away from the roadway, the less chance it has of getting struck by errant vehicles)
- Amount of fill necessary for installation (Typically guardrail is not flared when the fill height is greater than 10 feet unless crash history indicates it to be cost effective)
- Amount of surfacing required for installation
- Difference in guardrail length
- Cost

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

Only Tangent W Beam Guardrail End Terminals should be installed adjacent to areas with curb and gutter. See section regarding CURBS in this chapter.

The Tangent Guardrail End Terminal shall not be used in flared guardrail installations. If guardrail is flared prior to the end terminal, only the Flared W Beam Guardrail End Terminal shall be used.

At off-end W Beam End Terminals, where the traffic does not approach the guardrail (divided highways where traffic only travels in one direction), W Beam Trailing End Terminals may be used. The trailing end terminal should never be used where oncoming traffic could strike the end of the terminal.
Three Cable Guardrail 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 10-10) 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).

The Slip Base Three Cable Guardrail Anchor Assembly (Figure 10-11) is the standard end treatment for three cable guardrail. Forty feet from the first vertical post of this terminal is considered as non-effective for determining the length of the guardrail system needed.

Figure 10-10 Three Cable Guardrail Anchor Assembly

Figure 10-11 Slip Base Three Cable Guardrail Anchor Assembly
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, and utility poles. If these obstacles cannot be relocated, removed, or have an appropriate breakaway device then barrier would be required.

Several items must be determined 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, roadway design speed, and roadway characteristics (lane widths, shoulder widths, and steepness of slopes within the clear zone area).

The clear zone distance for the roadway can be determined by referring to the section for Clear Zone at the beginning of this chapter. If the roadside obstacle or slope is in the clear zone, measures will need to be taken to protect the traveling public from this hazard. A list of roadside obstacles is included in the section for Clear Zone.

If the roadside obstacle can be eliminated or removed by cost-effective measures without the use of a barrier or other safety feature, every effort should be used to do so.

If the roadside obstacle cannot be eliminated or removed, the designer must determine the most effective barrier that may be used for protecting the traveling public from the roadside obstacle.
Barrier Design Steps (See Figures 10-12, 10-13, and 10-14)

The equations in the design steps listed below shall be limited to straight or nearly straight sections of roadway. The equations will produce longer “Length of Need” than the graphical method when W Beam Guardrail Flared End Terminals are used. A graphical design for barrier may be the preferred choice to determine the required barrier lengths to install. The section for Barrier Design Examples at the end of the chapter provides further barrier design guidelines. The following is a suggested list of steps for barrier design:

1. Determine if barrier is required.

2. Assemble roadway data which shall include: the roadway posted speed, the directional average daily traffic (ADT) counts, the roadway characteristics (lane width (LW), roadway shoulder width (SW), and the structure shoulder widths (SB) (when structures are involved).

   Check the ADT. If the directional ADT is less than 500, consider using the minimum length guardrail. See Figure 10-15. The minimum length of guardrail is 81.25 feet with an effective length of 68.75 feet for Thrie Beam connection to a structure. The minimum length of guardrail is 75 feet for W Beam connection to a structure.

3. Determine the clear zone width which will vary depending on the type of project.

4. Determine the lateral distance to the roadside obstacle (LA). This distance is the distance from the edge of the traveled way to the far side of the fixed object or to the outside edge of the clear zone (whichever is less).

5. Determine the runout length (LR) using Table 10-10. The runout length is the theoretical distance needed for a vehicle that has left the roadway to come to a stop. It is measured from the upstream extent of the obstruction along the roadway to the point at which a vehicle is assumed to leave the roadway. To determine the runout length, two criteria are required, the design speed of the roadway and the directional ADT.

   a. The Speed used for barrier design are as follows:

      I. Interstate projects should use the current posted speed limit.

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

b. ADT used for barrier design are as follows:
   
   I. Interstate projects should always use 10,000+
   
   II. 3R projects should use the present ADT counts for **current** directional ADT (one way volume). *Example: 2000 current total ADT received from Transportation Inventory Management should be multiplied by the D=50% where the directional ADT equals 1000*
   
   III. Construction/Reconstruction projects should use the future design ADT counts for **future** directional ADT (one-way volume)

Table 10-10 Runout Length (L_R)

<table>
<thead>
<tr>
<th>Posted Speed mph</th>
<th>Runout Length^1 (L_R) in feet for Directional ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Over 10,000</td>
</tr>
<tr>
<td>80</td>
<td>470</td>
</tr>
<tr>
<td>75</td>
<td>415</td>
</tr>
<tr>
<td>70</td>
<td>360</td>
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<tr>
<td>65</td>
<td>330</td>
</tr>
<tr>
<td>60</td>
<td>300</td>
</tr>
<tr>
<td>55</td>
<td>265</td>
</tr>
<tr>
<td>50</td>
<td>230</td>
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<tr>
<td>45</td>
<td>195</td>
</tr>
<tr>
<td>40</td>
<td>160</td>
</tr>
<tr>
<td>35</td>
<td>135</td>
</tr>
<tr>
<td>30</td>
<td>110</td>
</tr>
</tbody>
</table>

^1 All mainline Interstates shall use 10,000+ directional ADT. Use table for Expressways.

The shy line (L_S) 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 highway's outside edge of finished shoulder is considered the shy line on all projects in the State of South Dakota.
6. Determine the flare rate \( (F_R) \) using Table 10-11. 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

The end terminals should not terminate inside the shy line \( (L_S) \); however, it is acceptable to place crash cushions (attenuators) inside the shy line for narrow structures or median barriers as necessary.

When providing a flare within a steel beam guardrail system, the PI location for the beginning of the flare shall be at the midspan of a steel rail section.

**Table 10-11 Flare Rate \( (F_R) \)***

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

* 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.

7. Calculate the length of need ($L_N$) which is the total length of a longitudinal barrier needed to shield an roadside obstacle.

The length of need can be determined either by drawing up the layout and determining lengths or by calculating the lengths with the formulas below. The lengths can then be verified by the drawing to be placed in the plans.

a) Two lane roadway - Full width shoulders

$$L_{NR} = \frac{(L_A - S_{WR}) L_R}{L_A}$$

$L_{NR}$ is the length needed on the right side of the roadway.

$$L_{NL} = \frac{(L_A - S_{WL} - L_{WL}) L_R}{L_A}$$

$L_{NL}$ is the length needed on the left side of the roadway.

![Figure 10-12 Typical Barrier Design for Two Lane Roads with Tangent Guardrail](image)

b) Two lane roadway - Reduced width shoulders on structure

On bridges that are narrower than the approaching roadway, the barrier may be flared if the length of need permits. If the barrier being installed is of minimal length, the barrier may be installed parallel to the roadway, however, a flared end must be specified for the termination of the W Beam Guardrail so the end of the terminal is beyond the approaching shy line.

All flared W Beam Guardrail installations must use a flared end terminal. Tangent terminals are not considered to be crashworthy on a flared installation.

($L_t =$ the distance from the structure to where the barrier begins to flare. Use 22.9 feet for a Thrie Beam connection, 30.1 feet for a W Beam connection with concrete end block type shown on standard plate 630.50, and 27.75 feet for a W Beam connection with needle nose concrete end block type shown on standard plate 630.55)
Length of Need equations for flared guardrail at narrow structures:

\[
L_{NR} = \left[ L_A + \frac{1}{F_R} (L_t) - S_{BR} \right] \\
\times \left[ \frac{1}{F_R} + \frac{L_A}{L_R} \right]
\]

\(L_{NR}\) is the Length of Need for the right side of the roadway

\[
L_{NL} = \left[ L_A + \frac{1}{F_R} (L_t) - S_{BL} - L_{WL} \right] \\
\times \left[ \frac{1}{F_R} + \frac{L_A}{L_R} \right]
\]

\(L_{NL}\) is the Length of Need for the left side of the roadway

Figure 10-13 Barrier Design for Two Lane Roads with Flared Guardrail at Narrow Structure.

Length of Need equations for flared guardrail at full roadway width structures:

\[
L_{NR} = \left[ L_A + \frac{1}{F_R} (L_t) - S_{WR} \right] \\
\times \left[ \frac{1}{F_R} + \frac{L_A}{L_R} \right]
\]

\(L_{NR}\) is the Length of Need for the right side of the roadway

\[
L_{NL} = \left[ L_A + \frac{1}{F_R} (L_t) - S_{WL} - L_{WL} \right] \\
\times \left[ \frac{1}{F_R} + \frac{L_A}{L_R} \right]
\]

\(L_{NL}\) is the Length of Need for the left side of the roadway

c) Median design

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 per Figures 10-15 and 10-16. When median widths exceed 80 feet, consider using an 80 foot offset to determine guardrail length.

If the structures are not skewed, both of the following equations can be used to determine $L_{3C}$. Substitute “0” for $L_X$ in either of the equations.

\[ L_{3C} = \text{length of 3 cable barrier needed from the W beam to 3 cable transition to the slip base anchor} \]
\[ L_X = \text{longitudinal distance from adjacent bridge end to obstacle due to bridge skew} \]
\[ L_T = \text{The distance from the structure to the PI (22.9 feet for Thrie beam connections, 30.1 feet for a W Beam connection with concrete end block type shown on standard plate 630.50, and 27.75 feet for a W Beam connection with needle nose concrete end block type shown on standard plate 630.55). The length is determined assuming 2.1’ of the Double (Nested) Thrie Beam guardrail laps onto the structure.} \]
\[ L_A = \text{Distance from traveled way to outside edge of obstacle or clear zone} \]
\[ F_R = \text{The flare rate (34:1 flare rate would be “34” in the equation for 80 mph posted speed and 32:1 flare rate would be “32” for 75 mph posted speed and less)} \]
\[ S_{WL} = \text{Inside shoulder width} \]
\[ L_R = \text{Runout Length} \]
Equation for determining length of 3 cable barrier needed from the W beam to 3 cable transition to the slip base anchor with structures skewed Left Hand Forward (LHF):

\[
L_{3C} = \left[ \frac{LA + (1/F_R) (LT + LX) - S_{wl}}{1/F_R + LA / LR} \right] - 93.75' - LT - LX
\]

Round \( L_{3C} \) to the next 16 foot increment.

---

Figure 10-15 Barrier Design for Divided Highways with Structures Skewed LHF

Equation for determining length of 3 cable barrier needed from the W beam to 3 cable transition to the slip base anchor with structures skewed Right Hand Forward (RHF):

\[
L_{3C} = \left[ \frac{LA + (1/F_R) (LT - LX) - S_{wl}}{1/F_R + LA / LR} \right] - 93.75' - LT + LX
\]

Round \( L_{3C} \) to the next 16 foot increment.
8. Determine what type of barrier(s) to install.

Barrier type is dependent upon the length being installed as it becomes more cost effective to transition to Three Cable Guardrail rather than continue a long length of W Beam Guardrail. Transitioning to Three Cable in long stretches reduces snow drifting problems.

Based on past cost comparisons:

- If the calculated length of need is less than or equal to 200 feet with a W Beam or Thrie Beam bridge end transition, the entire length of the barrier may remain steel beam.

- If the length of need is greater than 200 feet a W Beam to Three Cable Transition and Three Cable Guardrail may be installed.

The bridge end transition is dependent on the end block on the bridge:

- New bridges will have a Thrie Beam Transition.

- Existing bridges may have either type of transition. Review the structure sheets to determine the type of transition needed as referred to in the section for Barrier Transitions.

Figure 10-16 Barrier Design for Divided Highways with Structures Skewed RHF

9. Calculate the length of barrier required:

a) **Bridges with minimum length steel beam guardrail:**

If directional ADT < 500, a minimum length guardrail design can be used. The following listed segments for both Thrie Beam and W Beam connections off a bridge rail and Figure 10-17 defines the minimum length steel beam guardrail that can be used.

**Thrie Beam Connection**
- 12.5’ Double Class A Thrie Beam
- 6.25’ W to Thrie Beam Transition Section
- 25’ Straight Class A W Beam
- (37.5’ or 50’) W Beam End Terminal

Depending on the type of end installed, the total length = 81.25’ (flared end) or 93.75’ (tangent end).

**W Beam Connection**
- 12.5’ Double Class B W Beam Guardrail
- 12.5’ Class B W Beam Guardrail
- 12.5’ Class A W Beam Guardrail
- (37.5’ or 50’) W Beam End Terminal

Depending on the type of end installed, the total length = 75.0’ (flared end) or 87.5’ (tangent end)

---

**Figure 10-17 Minimum Length Guardrail Layouts**
b) **Bridges with W beam bridge end transition:**

i) Length of need $\leq$ 200' in Figure 10-18. The entire length of guardrail will be W Beam using an approved W Beam End Terminal from the approved products list.

Calculate guardrail length:

\[
L_N - xx.x' - 12.5' - 25' or 37.5' = L_1
\]

- $L_N$ Length of need
- $xx.x'$ Double Class B with Rubrail at structure (Depending on end block type add .7’ or 3.5’(needle nose type) to (-12.5’)) (Ex: -12.5 + .7 = -11.8’)
- 12.5’ Class B W Beam next to Double Class B
- 25’ or 37.5’ Effective length of W Beam End Terminal

Length of Class A W Beam required rounded up to next 12.5’

![Diagram of Bridges with W Beam Bridge End Transition](http://www.sddot.com/business/design/news/default.aspx)

**Figure 10-18** Bridges with W Beam Bridge End Transition ($L_N \leq 200'$)
ii) Length of need >200’ (Figure 10-19). Place minimum length guardrail (75’ including BCT) and transition to Three Cable Guardrail.

Calculate guardrail length:

\[ L_N \]

- \( xx.x' \) Double W Beam with Rubrail off the structure (Depending on end block type add .7’ or 3.5’(needle nose type) to (-12.5’)) (Ex: -12.5 + .7 = -11.8’)
- 100’ W Beam to 3 Cable Transition
- 8’ Effective length of 3 Cable Guardrail Anchor
= \( L_1 \) Length of 3 Cable Guardrail required within Length of Need rounded up to next 16’

Total 3 Cable Guardrail Length = \( L_1 + 100' + 8' + 43' \)

Figure 10-19 Bridges with W Beam Bridge End Transition (\( L_N > 200' \))
c) **Bridges with Thrie beam bridge end transition:**

i) Length of Need \( \leq 200' \) (Figure 10-20). The entire length of guardrail will be steel beam with Thrie Beam transitioning to W Beam. The W Beam will terminate using an approved W Beam End Terminal from the approved products list.

Calculate guardrail length:

\[
L_N \quad \text{Length of Need} \\
-10.4' \quad \text{Double Thrie Beam off the structure} \\
\quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad 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\quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \q
ii) Length of Need >200’ (Figure 10-21). Place minimum length guardrail (75’ (including BCT) and transition to Three Cable Guardrail.

Calculate guardrail length:

\[
\begin{align*}
L_N & \quad \text{Length of Need} \\
- 10.4' & \quad \text{Double Thrie Beam off the structure} \\
- 6.25' & \quad \text{Thrie Beam to W Beam Transition} \\
- 100' & \quad \text{W Beam to 3 Cable Transition} \\
- 8' & \quad \text{Effective length of 3 Cable Guardrail Anchor} \\
= L_1 & \quad \text{Length of 3 Cable Guardrail required within the Length of Need rounded up to next 16'}
\end{align*}
\]

Total 3 Cable Guardrail Length = 43' + 8' + L_1 + 100'

**Figure 10-21** Bridges with Thrie Beam Bridge End Transition (L_N>200’)

d) **W Beam guardrail protecting a roadside obstacle.**

i) *Length of Need ≤200’ (Figure 10-22).*

Calculate guardrail length:

\[
L_N - 25’ \text{ or } 37.5’ = L_1
\]

- \(L_N\) \: Length of Need
- Effective length of W Beam End Terminal
- \(L_1\) \: Length of Class A W Beam required rounded up to next 12.5’

**NOTE:** If closer post spacing is used for deflection control then the closer post spacing should begin 25 feet prior to the obstacle.

---

*Figure 10-22  W Beam Guardrail Protecting a Roadside Obstacle (L_N≤200’)*
ii) Length of need >200’ (Figure 10-23). Place minimum length of W Beam Guardrail as necessary and transition to Three Cable Guardrail to reach length of need. Three Cable Guardrail is installed to even 16’ increments.

Calculate guardrail length:

\[
\begin{align*}
L_N & \quad \text{Length of Need} \\
- 25' & \quad \text{Class A W Beam from object to W Beam to 3 Cable Transition} \\
- 100' & \quad \text{W Beam to 3 Cable Transition} \\
- 8' & \quad \text{Effective length of 3 Cable Guardrail Anchor} \\
= L_1 & \quad \text{Length of 3 Cable Guardrail required within Length of Need rounded up to next 16'} \\
\end{align*}
\]

Total 3 Cable Guardrail Length = 43’ + 8’ + L_1 + 100’

NOTE: If closer post spacing for steel beam guardrail is used for deflection control then the closer post spacing should begin 25 feet prior to the obstacle.

Figure 10-23 W Beam Guardrail Protecting a Roadside Obstacle (LN>200’)

Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates.  
e) Thrie Beam guardrail protecting a roadside obstacle.

i) Length of need ≤200’ (Figure 10-24).

Calculate guardrail length:

\[ LN \quad \text{Length of need} \]
\[-25’ \quad \text{Class A Thrie Beam from the object} \]
\[-6.25’ \quad \text{Thrie Beam to W Beam Transition} \]
\[-25’ \text{ or } 37.5’ \quad \text{Effective length of W Beam End Terminal} \]
\[ = L_1 \quad \text{Length of Class A W Beam Guardrail required rounded up to next 12.5’} \]

NOTE: If closer post spacing for steel beam guardrail is used for deflection control then the closer post spacing should begin 25 feet prior to the obstacle.

Figure 10-24 Thrie Beam Guardrail Protecting a Roadside Obstacle (LN ≤200’)

ii) Length of Need >200’ (Figure 10-25). Place minimum length steel beam guardrail as necessary and transition to Three Cable Guardrail.

Calculate guardrail length:

\[
L_N - 25' \quad \text{Class A Thrie Beam from the object}
\]
\[
- 6.25' \quad \text{Thrie Beam to W Beam Transition}
\]
\[
- 100' \quad \text{W Beam to 3 Cable Transition}
\]
\[
- 8' \quad \text{Effective length of 3 Cable Guardrail Anchor}
\]
\[
= L_1 \quad \text{Length of 3 Cable Guardrail required within Length of Need rounded up to next 16'}
\]

Total 3 Cable Guardrail Length = 43’ + 8’ + L_1 + 100’

**Figure 10-25** Thrie Beam Guardrail Protecting a Roadside Obstacle (L_N>200’)
f) Three Cable Guardrail protecting a roadside obstacle (Figure 10-26).

Calculate guardrail length:

\[ L_N - 8' = L_1 \]

Length of Need
Effective length of 3 Cable Guardrail Anchor
Length of 3 Cable Guardrail required
within Length of Need rounded up to
next 16'

Additional posts may be required at and prior to the object location. Refer to the Standard Plates for additional posts required.

Figure 10-26 Three Cable Guardrail Protecting a Roadside Obstacle
g) **Concrete Barrier protecting a roadside obstacle (Fig 10-27).**

Calculate barrier length:

\[
L_N \quad \text{Length of Need} \\
- \text{Length of non-gating crash cushion/attenuator} \\
= L_1 \quad \text{Length of concrete barrier required} \\
\text{rounded up to next 1'}
\]

**Figure 10-27** Concrete Barrier Protecting a Roadside Obstacle

h) **Median Design with Thrie Beam off the structure (Figures 10-15, 10-16, and 10-21)**

Calculate the length of Three Cable Guardrail needed with standard post spacing:

\[
L_N \quad \text{Length of Need} \\
- 10.4' \quad \text{12.5' Double Thrie Beam (2.1' on structure)} \\
- 6.25' \quad \text{Thrie Beam to W Beam Transition} \\
- 100' \quad \text{W Beam to 3 Cable Transition} \\
- 8' \quad \text{Effective length of 3 Cable Guardrail Anchor} \\
= L_1 \quad \text{Length of 3 Cable Guardrail required} \\
\text{within Length of Need rounded up to next 16'}
\]

Total 3 Cable Guardrail Length = 43’ + 8’ + L_1 + 100’
i) Median Design with W Beam off the structure

Calculate the length of Three Cable Guardrail needed with standard post spacing (Figure 10-15, 10-16, and 10-19)

\[ L_N \] Length of Need
- \( xx.x' \) Double Class B with Rubrail at structure (Depending on end block type add .7’ or 3.5’(needle nose type) to (-12.5’)) (Ex: -12.5 + .7 = -11.8’)
- 12.5 Single Class B W Beam
- 100’ W Beam to 3 Cable Transition
- 8’ Effective length of 3 Cable Guardrail Anchor
= \( L_1 \) Length of 3 Cable Guardrail required within Length of Need rounded up to next 16’

Total 3 Cable Guardrail Length = 43’ + 8’ + \( L_1 \) + 100’

10. For a Grading and Interim Surfacing project, occasionally the designed guardrail may not be included with these plans, however the appropriate information needs to be provided so any preparation construction work (i.e. subgrade widening) can be included with this project. Typically during the scope process a determination should be made when the guardrail should be installed. Options may include:
   a) install temporary signs/barricades within the construction zone to warn vehicles of the roadside obstacle and then install the guardrail on the Surfacing Project
   b) install guardrail at an interim height and take out and reinstall on the Surfacing Project
   c) provide ultimate surfacing at the guardrail locations on the Grading and Interim Surfacing Project and install guardrail at correct height

Decisions may vary on the type of roadside obstacle, durations to final surfacing, ADT, etc.

11. Document the results and place in the project computation file.
TEMPORARY BARRIERS

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 to be protected and allow for deflection of the barriers where practical.

Table 10-12  Deflection of Movable Concrete Barrier

<table>
<thead>
<tr>
<th>Barrier Type</th>
<th>Approximate Deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>F shape</td>
<td>3'-6&quot;</td>
</tr>
<tr>
<td>Jersey shape</td>
<td>4'-0&quot;</td>
</tr>
</tbody>
</table>

1 not pinned to ground or surface
2 based on high speed situations where possible impact angles are 20 degrees

A basic layout of temporary concrete barriers shown in Figure 10-28 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 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 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 speeds of 45 mph or greater. A TL-2 MASH or NCHRP 350 crash attenuator may be used for 40 mph speed. Where traffic 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 considered. 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. It should also be made known to those involved that in the case of a severe hit that even these barriers will deflect and may not always properly redirect a vehicle hitting them. This is intended only as a warning to NOT get a false sense of security for those working behind the barriers or for items placed immediately behind them.

For urban and suburban projects, use of the temporary concrete barriers should be discussed at the scoping meetings. Depending on the traffic counts, traffic 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* in regards to use of temporary concrete barriers. The guardrail contact person for South Dakota is another resource to provide help for decisions regarding temporary concrete barrier use in urban and suburban areas.

![Figure 10-28 Temporary Barrier Design](image-url)
Read the standard specifications sections 629 and 630 as well as the standard plates in the 629 and 630 series for additional bid item information in regards to measurement and payment as all the items are not listed and described below. Also, remember that notes in the plans overwrite which is covered in the standard specifications. Do not write plan notes that replicate or modify which is already on the standard plates or standard 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 shall be in like new condition where there are no tears and no extra holes in the steel beam. Cable that is reset shall be in good condition with no broken strands in the cable clusters.

**Straight Thrie Beam and W Beam Guardrail**

Straight Class A or B Thrie Beam and W Beam Guardrail with Wood Posts are paid for by the foot (meter) 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 rail (nested) as well as the required posts, blockouts, and hardware necessary for installation.

**Curved Thrie Beam and W Beam Guardrail**

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 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.
W Beam Guardrail Flared or Tangent End Terminal

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 shall 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 two tangent end terminals on the approved product lists.

W Beam to Thrie Beam Guardrail Transition

W Beam to Thrie Beam Guardrail Transitions are paid for per each and includes cost for all labor, equipment, and materials including the 6.25 foot transition section, two guardrail posts with blockouts, and hardware necessary for installation of the transition section.

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

The W Beam Guardrail to Three Cable Guardrail Transition is not a pay item. The portions of the transition shall 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

3 Cable Guardrail is paid for by the foot (meter) and includes cost for labor, equipment, and materials including all posts, cables, and hardware necessary for the installation of the 3 cable guardrail.

Three Cable Guardrail Anchor Assembly

3 Cable Guardrail in the 3 Cable Guardrail Anchor Sections is paid for by the foot (meter) 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 shall be a MASH or NCHRP 350 device that is designed for the traffic condition it is being used for. See Section B – Grading Standards notes regarding the Permanent Concrete Barrier End Protection plan note for more information.

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 DOT 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 Standards 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 traffic detours/diversions, 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 shall be a MASH or NCHRP 350 device that is designed for the traffic condition that it is being used for. 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 modules 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 shall 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

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 (meter) basis. New bridge railing is designed to connect to double (nested) thrie beam guardrail making the use of rubrail not necessary.

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 (meter)). 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: Three Cable Guardrail**

**Design Factors:**

- Roadside Obstacle: Bridge Column (outside shoulder)
- Highway: Non-Interstate
- Reconstruction Clear zone = 30’
- Protection Limit: 23’ (back of column)
- Distance to hazard: 21’ (2’ wide column)
- Shoulder Width ($S_W$) = 6’
- ADT (directional) = 1200
- Design Speed = 65 mph

**Calculations:**

Determine Runout Length using Table 10-10 for given ADT and design speed
\[ \therefore L_R = 250’ \]

Determine Length of Need
\[
L_N = L_R \left( \frac{L_A - S_W}{L_A} \right)
\]
\[ L_N = 250 \left( \frac{23 - 6}{23} \right) = 185’ \]

Since $L_A - S_W = 17’$, from Table 10-8 use 3 cable guardrail at 16’ post spacing with a 15’ maximum deflection.

Determine how much tangent rail ($L_1$) needed:
\[ L_1 = L_N - 	ext{Effective length of 3 cable guardrail slip base anchor (8’ is effective of 51’)} \]
\[ L_1 = 185’ - 8’ = 177’ \]
\[ 177’/16’ lengths = 11.06 \text{ (round up to 12)} \]

**Design Layout:**

Place 12 lengths of 3 cable guardrail at 16’ spacing beginning at the hazard location and add the 3 cable guardrail slip base anchor section to the drawing.

Design the guardrail for the opposing traffic. Because the distance (33’) from the centerline of the roadway to the obstacle is greater than the clear zone distance (30’), the object does not warrant protection from the opposing traffic.
Extend the 3 cable guardrail one post past the obstacle at the off-end of the guardrail (See standard plate titled “3 Cable Guardrail Post Spacing for Deflection Control) and add the 3 cable guardrail slip base anchor terminal.

Label the guardrail elements in the layout. Be sure to provide a tie to the topography as to where the guardrail will be placed. The tie can be stationing or dimensioning. Label the extra embankment needed.

Place the drawing on a plan sheet for inclusion in the plans. Refer to Chapter 18 – Plans Assembly for Guardrail Layout sheet.

Tabulate the guardrail bid items:

3 cable guardrail slip base anchor assembly: 2 Each
3 cable guardrail: 208’ + 2 (43’ + 8’) anchors = 310 Ft

Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates.  
Design Example 2: W Beam or Thrie Beam Guardrail

Design Factors:

- Roadside Obstacle: Bridge Columns (outside shoulder)
- Highway: Interstate
- Reconstruction Clear Zone = 30'
- Protection Limit: 18.1' (Back of Column)
- Distance to hazard: 13.1' (5' diameter columns)
- Shoulder Width ($S_{WR}$) = 10'
- ADT (directional) = 5615
- Design Speed = 75 mph

Note: If there is a 2:1 bridge embankment approach within the clear zone, the slope out to the clear zone would be the obstacle for determining the length of need and the columns would need to be reviewed for need of deflection control. A longer length of guardrail would occur if protecting out to the clear zone.

Calculations:

Determine Runout Length using Table 10-10 (ADT & Design Speed are immaterial for Interstate).

$$LR = 415'$$

Determine Length of Need

$$L_NR = LR \frac{(L_A - S_{WR})}{L_A}$$

$$L_NR = 415 \frac{(18.1 - 10)}{18.1} = 185.7'$$

Since $L_A - S_{WR} = 3.1'$, from Table 10-8 it would appear that W Beam at 3.125' post spacing with a 2' maximum deflection would be adequate; however, if one of the posts is located in front of the column, then the deflection should be based from the back of the post to the column. The deflection used should be

$$= 3.1' - (3.25(rail)+8(blockout)+8(post)/12) = 1.5'$$

Therefore, it would be conservative to use Double (Nested) Thrie Beam with post spacing of 3' – 1 ½” as the deflection is .75’.

Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates.
Check to see if the steel beam should be transitioned to 3 cable:
Since $L_N \leq 200'$, use Double (Nested) Thrie Beam and transition to W Beam
If $L_N > 200'$, transition Double (Nested) Thrie Beam to W Beam and then transition to 3 cable

Begin at edge of column and work back. When using reduced post spacing, the post spacing needs to begin 25 feet before the first hazard. Note: Care should be taken to avoid placing a post directly in front of a column unless sufficient space is provided for the required deflection.
Determine how much tangent guardrail (L₁) is required to the end terminal.

\[ L₁ = 185.7' \quad (L_{NR}) \]
- \(25'\) (Double (Nested) Thrie Beam at reduced (3'- 1 ½") post spacing)
- \(6.25'\) (W Beam to Thrie Beam transition)
- \(37.5'\) (effective length of Tangent End Terminal)
\[ L₁ = 116.95' \quad \text{rounded up to next 12.5 increment} = 125.0' \text{ of guardrail required.} \]

The Designer will choose what W Beam Guardrail End Terminal (Flared or Tangent) to use. Place the end terminals on the drawing.

Note: because of the 50:1 flare the tangent terminal is installed on, the protection line crosses further down the proposed installation.
Reduce the length of guardrail the maximum amount possible so the protection line intersects the guardrail within the effective length area.

Length was reduced 50’ using the Flared End Terminal and was reduced 12.5’ using the Tangent End Terminal.

Consider flaring the guardrail based on the following:
- Crash History (If there are higher number of crashes then consider flaring the guardrail away from the roadway. The further guardrail is away from the roadway, the less chance it has of getting struck by errant vehicles)
- Amount of fill necessary for installation (Typically guardrail is not flared when the fill height is greater than 10 feet unless crash history indicates it to be cost effective)
- Amount of surfacing required for installation
- Difference in guardrail length
- Cost

Design the guardrail using a 16:1 flare rate using Table 10-11 (75 mph and Outside Shy Line)

Guardrail can be flared beginning in the middle of the first 12.5’ of W beam with normal post spacing. Note: Tangent end terminals CANNOT be used in installations where the guardrail is placed on a flare.
Continue from PI and place W Beam guardrail. Attempt placing the flared end terminal to check if the effective length crosses the protection line.
Try removing one 12.5' length of W beam. In the following drawing the guardrail effective length no longer crosses the protection line creating an unacceptable installation.

The guardrail on the off-end needs to be extended past the last column (roadside obstacle) before terminating.
Place an end terminal on the off-end. Because there is no opposing traffic on Interstate, a W beam trailing end terminal can be used. Since the Double Thrie Beam has post spacing of 3’-1 ½”, one post needs to be removed from the drawing because the Trailing End Terminal has a post spacing of 6’-3”.

![Diagram of guardrail elements](image)

NOTE: For two lane roads, design would need to be done for the opposing traffic.

Label the guardrail elements in the layout. Be sure to provide a tie to the topography as to where the guardrail will be placed. The tie can be stationing or dimensioning.

Place the drawing on a plan sheet for inclusion in the plans. Refer to Chapter 18 – Plans Assembly for Guardrail Layout sheet.

Tabulate the guardrail bid items:

**Flared Installation:**
- Straight Double Class A Thrie Beam Guardrail with Wood Posts: 50 Ft
- W Beam to Thrie Beam Guardrail Transition: 1 Each
- Straight Class A W Beam Guardrail with Wood Posts: 25 Ft
- W Beam Guardrail Flared End Terminal: 1 Each
- Beam Guardrail Trailing End Terminal: 1 Each

**Tangent Installation:**
- Straight Double Class A Thrie Beam Guardrail with Wood Posts: 50 Ft
- W Beam to Thrie Beam Guardrail Transition: 1 Each
- Straight Class A W Beam Guardrail with Wood Posts: 112.5 Ft
- W Beam Guardrail Tangent End Terminal: 1 Each
- Beam Guardrail Trailing End Terminal: 1 Each

Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates. 
Design Example 3: Guardrail at a Bridge

Protection at a structure is similar to that previously discussed in example 1 and 2 with few exceptions:

- Connection to the structure
- The structure is protected for on-coming traffic only

There are two scenarios for the connection to the structure:

- Double (Nested) Thrie Beam (The only connection SDDOT uses that currently meets NCHRP 350)
- Double (Nested) W Beam
  - Being phased out as the connection does not meet NCHRP 350
  - Requires the use of Rubrail (Rubrail is an additional rail added below the W beam connection to reduce the snagging of the wheel on the structure)

Design Factors:

- Roadside Obstacle: Bridge Rail End and Steep Bridge Berm Slope
- Highway: Non-Interstate
- Reconstruction Clear Zone = 30’
- Determine the width that needs protection
  - Protect for the structure only?
  - Protect beyond the structure (steep bridge berm slope)?
- Lane width ($L_w$)
  - Roadway = 12 ft
  - Bridge = 12 ft
- Shoulder Width ($S_w$)
  - Roadway = 6 ft
  - Bridge = 6 ft
- ADT (directional) = 850
- Design Speed = 65 mph

Please refer to “Temporary Guidance for New 630 Series (Steel Beam Guardrail) Standard Plates” as Chapter 10 does not currently address designs associated with the new plates.

Design Layout:

Show the structure, the roadway and the area requiring protection

Determine Runout Length using Table 10-10 for given ADT and design speed. 
∴ \[ L_R = 225'' \]

If directional ADT < 500, minimum length guardrail can be used. 
ADT(dir) = 850; therefore, guardrail must be designed.
Based on the runout length as measured from edge of traveled way to clear zone in the previous drawing, the Length of Need (L_N) is determined from end of bridge rail to a distance where the protection line intersects the guardrail location at the edge of shoulder.

\[
\begin{align*}
L_{NL} &= 90' \\
L_{NR} &= 180'
\end{align*}
\]

As the length of need is less than 200', the entire length should be steel beam.

As this structure is new, the connection will be Thrie Beam off the bridge rail and will transition to a W Beam. Note: All Interstate structures will also be upgraded to accept Thrie Beam as projects are scheduled in the STIP.

Transition to W Beam and Continue
Continue Placing W Beam towards the end of the protection line.

Place the W Beam End Terminal at the protection line. You will need to lengthen or shorten the W beam until the protection line is just within the effective length of the terminal end section. The option of using a Flared or Tangent End Terminal is the designer's choice based on the site conditions. Flared End Terminals were used in this example.

Design the guardrail for the left shoulder using the same steps.
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 or dimensioning.

Place the drawing on a plan sheet for inclusion in the plans. Refer to Chapter 18 – Plans Assembly for Guardrail Layout sheet.

Variations for Guardrail at Structures

a) W Beam off the structure (requires rubrail)
b) Transition to 3 Cable (vs. continuous W Beam)
   1. Use minimum length guardrail off the structure (W or thrie beam (W Beam Shown))
   2. Transition from W beam to 3 cable guardrail (100' length)
   3. Place 3 cable guardrail in 16' increments
   4. Place 3 cable guardrail anchor section

NOTE: 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.

Tabulate the guardrail bid items.
Design Example 4: Guardrail in the Median

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, consider using 80 foot offset to determine guardrail length.

Design Layout:

Show the structure, the roadway, and the area requiring protection.

Determine Runout Length (measured from the opposing structure) using Table 10-10 for given ADT and design speed.

Add the Protection Line to the layout.

Design the guardrail off the structure as previously discussed.

Flare the guardrail in the median to reduce the length needed using Table 10-11.
Transition to 3 cable.

Continue 3 Cable Guardrail until it crosses the protection line.

Add the 3 Cable Guardrail Slip Base Anchor. The slip base cables cannot be used when determining the effective length of guardrail.
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 a Guardrail Layout sheet.

Tabulate the guardrail bid items