Survey of Guardrail End Treatment Usage

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Study Title: Evaluation of Highway Safety Barriers

Whenever a guardrail terminates within the "clear zone," a crashworthy end treatment is required. To be crashworthy, the end-treatment should not spear, vault, or roll a vehicle during a head-on impact while maintaining vehicle decelerations below recommended limits. As a means of determining types of end treatments currently used in various states and criteria to determine what type to use, a survey letter was sent to each state.

It was found that, generally, the preferred method to use to end roadside steel beam guardrail is to bury the end in a cut slope. When this is not feasible, either a Breakaway Cable Terminal (BCT) or turned-down end treatment is generally used. While the BCT is used most often, some states use both, while others use only the turned-down end. There is considerable uniformity in the design of the BCT while there is a substantial diversity in the design of turned-down end treatments.

Recommendations were made concerning the type of end treatments which should be used in Kentucky for roadside steel beam guardrail. A design for a turned-down end treatment was proposed.
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SURVEY OF GUARDRAIL END TREATMENT USAGE

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and

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INTRODUCTION

Whenever a guardrail terminates within the "clear zone," a crashworthy end treatment is desired. To be crashworthy, the end treatment should not spear, vault, or roll a vehicle during a head-on impact while maintaining vehicle decelerations below recommended limits (1, 2). Also, for impacts between the end and standard section, the end must be properly anchored so it has the same redirectional characteristics as the standard roadside barrier.

There have been several modifications in recommended standards used for guardrail end treatments. For W-beam guardrail, the end treatment originally involved adding a slightly flared end shoe to the guardrail. However, that treatment was ineffective because of the tendency of the guardrail to spear the vehicle during head-on impacts. That treatment was replaced by a standard specifying the end to be twisted 90 degrees and anchored to the ground. That eliminated the spearing problem but created the potential for vehicles to vault or rollover after head-on impacts. Modifications have been made in the design of the treatment to alleviate the problem (3).

The current recommended standard is the breakaway-cable-terminal (BCT). The end treatment consists of a rail placed in a 37.5-foot parabola with the end post offset 4 feet from the back of the rail for the straight section. For head-on impacts, the flare causes vehicle forces to be introduced into the rail eccentrically, reducing the column strength of the rail, thus reducing the tendency for spearing. The first two posts have a hole bored in them, when wood, or have a slipbase, when steel, so they will break during a head-on impact. The breaking of the end post minimizes spearing forces while breaking the second post reduces the tendency for the rail to act as a ramp. The posts are anchored to reduce the tendency for the post to rotate in the soil, assures that the post will break upon end impacts. A curved terminal section distributes loads over a large area and lessens chances of spearing. The guardrail is attached by a cable to the end post. The cable transfers forces from beam to end post and is needed to resist impact downstream from the end.

Another alternative involves terminating and anchoring the guardrail end into a cut slope. The treatment is considered adequate but should only be used when the end can be flared and introduced at full height into the cut slope.

The previously discussed end treatments are used with steel W-beam guardrail, which is the most common type used. Other types of guardrail include box beam and cable, which also may have different types of end treatments.

When guardrail is installed in a median, designs are usually different from those used for roadside barriers. Median barrier guardrail systems are classified as flexible or semirigid (1). The flexible median barrier will deflect upon impact. The semirigid median barrier will deflect moderately and will reduce impact forces on vehicle passengers. The treatment used may vary with median width and type of obstruction.

The various end treatments provide alternatives that may be used. Kentucky, as well as other states, continues to have problems as design of guardrail end treatments evolves. The currently recommended design used at earth and/or soft rock cut sections is the buried end-treatment (Kentucky's Type 3). On all fills and solid rock cut sections having an adequate vehicle recovery zone behind the guardrail, the breakaway-cable-terminal (BCT) end treatment (Kentucky's Type 4) is recommended. For solid rock cut sections not having an adequate recovery zone behind the guardrail, the cable-anchored curled-terminal section (Kentucky's Type 2A) is recommended. Complicated and changing designs for guardrail end treatments have created significant maintenance problems when the guardrail must be replaced. Criteria or guidelines for replacement of damaged guardrails would aid maintenance personnel.

As a means of determining types of end treatments currently used in various
states and criteria to determine what types to use, a survey letter was sent to each state. Information concerning guardrail end-treatment standards and their related warrants were requested. This report documents the results of the survey. Included is data on different end treatments and related guidelines for their use. Recommendations for guardrail end-treatment usage in Kentucky are also presented.

SURVEY RESULTS

The survey letter was sent to a design engineer in each state explaining the objectives of the study and the information requested. A copy of the letter is included as Appendix A. Responses to that letter were received from 45 states. States not responding to the letter were contacted by phone so that input was obtained from all 50 states.

Information obtained was summarized by two methods. A summary on a state-by-state basis is presented in Appendix B. A format was selected for use in summarizing responses from each state. The outline is as follows:

A. Roadside Steel-Beam
   1. BCT
   2. Turned-Down
   3. Other

B. Other Types of Roadside Guardrail
C. Median-Barrier End Treatments
D. Guidelines

The second summary was by type of end treatment. The same outline as that used for the state-by-state summary was used. However, in the second summary, responses from all states concerning a given end treatment were combined. Following is a discussion of the summary.

ROADSIDE STEEL-BEAM GUARDRAIL

The most common guardrail used is the steel (W-beam) guardrail. While some states use other types of guardrail, all use the steel beam to some degree. The most common approach end treatments currently used for steel-beam guardrails include the BCT, the turned-down, and burying the end in a cut slope.

There was a general consensus among most states that burying the guardrail end in a cut slope was the preferable end treatment. However, this may only be done where roadway geometries allow. In lieu of this treatment, either the BCT or turned-down end treatment is commonly used. The most common end treatment used was the BCT with 40 states listing use of this treatment to some degree. A large number of states (24) noted use of the turned-down end treatment. In 14 states, both the BCT and turned-down treatments were used. A summary, by state, of use of either BCT, turned-down, or other steel-beam approach end treatments (excluding burying end in cut slope) is presented in Table 1. In 24 states, only the BCT is used. In eight states, only the turned-down treatment was used. Of the 14 states in which both BCT and turned-down treatments were used, responses indicated 5 preferred BCT, 5 preferred turned-down, and preference could not be determined in 4 instances.

Seven states indicated they used approach end treatments other than the BCT, turned-down, or buried-in-cut-slope. The end treatment preferred in Hawaii involved flaring the guardrail into an earth mound. Idaho also uses an earth mound for roadside guardrail end treatments. Another type of approach treatment involved flaring a nonbreakaway end treatment away from approach traffic. That treatment is more commonly used on low volume highways.

Following is a more detailed summary of the types of roadside guardrail used.

The summaries are for BCT, turned down, and "other". The other treatments include buried-in-cut-slope, downstream (trailing) terminal, earth mound, and flared, nonbreakaway treatment.

Breakaway-Cable-Terminal

The breakaway-cable-terminal (BCT) end treatment was used with roadside steel-beam guardrail in 40 states. As previously noted, the BCT was the preferred end treatment when the guardrail end could not be buried into a cut slope. BCT's are generally categorized as either a wood-post or steel-post design.
Specifications for those two types of design are presented in the American Association of State Highway and Transportation Officials' (AASHTO) publication titled "Guide for Selecting, Locating, and Designing Traffic Barriers" (1). The AASHTO design guide is the most current recommended procedure for end treatments, and wood-post and steel-post designs are considered to be acceptable operational end treatments. For those BCT designs, the "length of need" should be considered to begin at the third post (12.5 feet) from the end. Details of the flare, position, and offset of posts used in the typical BCT end treatment are shown in Figure 1. Details of the typical construction of the breakaway portion of the BCT end treatment are shown in Figure 2.

Results from the survey were compared to recommended AASHTO designs (1). Table 2 is a summary of BCT specifications from each of the 40 states reporting its use. Included in the Table 2 are 11 categories of specifications that represent most major design features of the BCT.

The length of parabola is the end-treatment length from terminal post to the tangent section of guardrail when the curved flare is known to be parabolic. Flare distance is the same section between terminal post and tangent section when the flared section is not specified as parabolic. In 29 of the 40 states, the length of parabola was 37.5 feet. Only two other states (Delaware and Louisiana) had a parabola that was different in length. The flared section was not specified as parabolic in nine states. Flare distance was greatest in Oregon, where the flare length varied from 50 feet to 112.5 feet.

Offset distance is the lateral distance between the face of guardrail at the terminal post and back of rail at the tangent section. In 31 states, the offset was specified as 4 feet. Acceptable ranges of offset distances in other states varied from 1 to 4 feet in Illinois to 4 to 10 feet in Oregon.

Spacing of posts was compared to AASHTO standards for wood-post and steel-post designs. As shown in Figures 1 and 2, the spacing of posts is different for the wood-post as compared to the steel-post design. In the wood-post design, all end-treatment posts are spaced at 6.25-foot intervals. For the steel-post design, the terminal posts (two posts at the end) are spaced at 6.25 feet; the next three posts are spaced at 4.17 feet; and the last two posts are spaced at 6.25 feet. In 35 states, post spacings were as recommended in the AASHTO guidelines. California uses a spacing of 6.25 feet for both wood- and steel-post designs. Maine uses AASHTO steel-post spacing for both wood- and steel-post designs.

Terminal posts are the two breakaway posts at the end of the flared section. Those posts may be either wood (usually 6 by 8 inches) or steel (6 by 6 by 0.1875 inches). Wood terminal posts were used exclusively in 30 states and steel terminal posts were used exclusively in 3 states. In seven states, both wood and steel terminal posts were used.

Approach posts are those between the two terminal posts and the tangent section guardrail posts. For the wood-post design, there are five approach posts, including the one at the beginning of the tangent section. For the steel-post design, there are six approach posts, including the one at the beginning of the tangent section. In 18 states, wood approach posts were used, without steel posts as an alternate. Steel posts were used exclusively in seven states. In 15 states, both wood and steel approach posts were used.

The method of anchoring terminal posts also varied throughout the states. However, all methods fell within the general categories of concrete anchor or steel-tube anchor. The steel-tube anchor, which was used exclusively in seven states, was generally used to secure wood terminal posts. Exceptions included Alabama, Illinois, and Maine, where both wood and steel terminal posts were anchored in steel tubes. In 19 states, the concrete anchor was used without the steel tube as an alternate. Both the concrete anchor and the steel-tube anchor were used in 11 states.

A final specification for BCT end
treatments included in the summary was the use of a diaphragm in the nose section. A diaphragm generally is used to strengthen the buffer end section, which usually is a thin piece of steel sheet metal. The end section is easily damaged by slight impacts of mowing or maintenance vehicles. An additional purpose of the diaphragm is to reduce the possibility of spearing during straight-on collisions between small cars and the BCT end treatment. It was noted that eight states used diaphragms in the end buffer section.

**Turned-Down End Treatment**

This type of end treatment was used in 24 states. As opposed to the BCT, there is no recommended national standard. Specifications vary from state to state. The general trend has been to provide for a longer twisted section than the original design to alleviate vaulting and rollover problems. Additional modifications have been made to the turned-down treatment to eliminate ramping and rollover problems. Examples of types of turned-down end treatments are shown in Figures 3-5.

A summary (by state) of some specifications that describe the turned-down end treatment is presented in Table 3. Portions of specifications summarized include total length of the end treatment, distance guardrail is twisted, end-treatment distance prior to twist, distance from last post to end, and end offset distance.

The average total length of turned-down end treatment was 48 feet. The length varied from a maximum of 150 feet to a minimum of 11 feet. The total length may generally be divided into two sections; the distance the guardrail is twisted, and a distance prior to the twist. The average distance the guardrail was twisted 90 degrees and anchored was 26 feet. In 18 of the 24 states, the distance the guardrail was twisted was 25 feet (for at least one type when two alternatives were given). In two states, the guardrail was not twisted but was slanted into the ground. In seven states, the end anchor was buried along with approximately one half of the twisted rail.

The end treatment extended in advance (upstream) of the twisted portion in 15 states. That distance averaged 34 feet in those states and consisted of either a section of guardrail having increased post spacings (typically 12.5 feet instead of the standard 6.25 feet) or a flared section of rail or a combination of those two features.

The distance from the last post to the end averaged 18 feet. That distance was equal to the distance the guardrail was twisted in 15 of 28 specifications. In most cases, no posts were placed in the twisted section.

The guardrail end (anchor) was offset in 17 of the specifications. The offset distance was measured from the typical line of guardrail. For those having an offset, the average offset distance was 4.4 feet.

Two specifications provided a weakened connection between the guardrail and last five posts. In another instance, the first three wood posts were weakened by a hole drilled in the posts. The purpose of those modifications was to minimize the problem of vaulting or rollover associated with the original design of a turned-down end treatment.

**Other Roadside Steel-Beam End Treatments**

In addition to the BCT and turned-down treatments, specifications for other end treatments were given by several states (Table 4). For approach end treatments, the buried-in-cut-slope was listed most frequently. Some other states provided information on their end treatment used in rock cut sections.

Other categories of approach end treatments included a flared nonbreakaway treatment and a treatment utilizing an earth mound. Several states provided specifications for their downstream (trailing) end treatment.

**Buried-in-Cut-Slope — Specifications**

for this end treatment were sent by 22 states. Other states probably also use this end treatment. In a large number of instances, this was given as the best approach end treatment alternative. The treatment involved flaring the guardrail across the ditch while maintaining the
standard guardrail height and then burying and anchoring the guardrail end into a cut slope. Either the guardrail end or the last post was buried in a concrete anchor. The typical length of buried rail was 6 to 12 feet. The typical minimum depth of burial to the top of the rail was one foot.

The rail was flared in the cut slope using either a constant flare rate of about 10:1 to 12:1 or a parabolic or circular flare. The end was offset from the line of guardrail. The offset varied, and most were approximately 10 feet. The length of flare varied and averaged slightly under 100 feet. A typical design for the buried-in-cut-slope end treatment is shown in Figure 6.

Rock Cut -- For a rock cut section, the rail was flared in a manner identical to that used for a cut slope. However, the end of the rail was either attached to the rock cut or ends with a cable terminal next to the cut.

Flared Nonbreakaway -- Five states listed approach end treatments in which the rail was flared with a buffer nonbreakaway end terminal. That treatment was generally used on low standard roadways. The end was offset an average of about five feet from the line of guardrail. The length of flare was short and used a curved section of rail that had a small radius. Specific details for the five states presented may be found in the state-by-state summary in Appendix B.

Earth Mound -- Two states (Hawaii and Idaho) gave specifications for earth-mound end treatments for roadside guardrail. Details of those end treatments are included in Appendix B.

Downstream (Trailing) End Treatment -- Twenty-three states provided specifications for the downstream end treatment used where the end is not exposed to opposing traffic. The treatment involved a cable anchoring system to add strength for impacts close to the downstream end.

Generally, the end treatment involved anchoring the guardrail with a cable and rod attached to the guardrail between the first and second post and to a buried concrete anchor placed some distance (typically 5 to 6 feet) behind the last post (Figure 6). One alternative in some instances involved anchoring the guardrail to the end post as in the BCT (Figure 8).

OTHER TYPES OF ROADSIDE GUARDRAIL

Steel-beam (W-beam) guardrail is used predominantly in the United States, however other types of roadside guardrail are used. Cable guardrail was listed for use by 10 states. Five sent information concerning use of a box-beam guardrail and one state mentioned use of steel-tube and aluminum guardrail. Other states also may use those types of guardrail since the survey dealt with steel-beam guardrail and information concerning other guardrail types was not specifically requested.

Cable -- All cable end treatments involved anchoring the cables in the ground. The average terminal length was 33 feet having a distance of 16 feet from the last post to the end anchor and an offset at the end of 3.5 feet.

Several states used a similar type end treatment (Figure 9). It involved a total terminal length of 42 feet. In that length, the post spacing decreased from the typical 16-foot spacing to from 6 to 8 feet. The cable was twisted and anchored over a distance of 18 feet with the end anchor offset 4 feet from the regular line of guardrail.

Box Beam -- Of the five states listing this type of guardrail, four flared the end into the ground. The remaining state used a BCT end treatment having a transition to the box-beam guardrail. Appendix B should be referred to for specifics about the box-beam end treatments.

Steel Tube and Aluminum -- Indiana was the only state listing these types of guardrail, and end treatments used were similar. The end was buried over a length of 40 feet. A maximum post spacing of 13.3 feet was specified in that end section. The end treatment was attached to the longitudinal rail with a rail splice and slanted into the ground with no offset.
MEDIAN-BARRIER END TREATMENTS

The survey letter did not request specifications for median-barrier end treatments, but information provided by 32 states allowed documentation of end treatments used in the median. Either a breakaway design (16 responses) or the turned-down design (15 responses) was used in most cases. A nonbreakaway design or earth mound was used in a few instances. Specific details may be found in the state-by-state summary given in Appendix B.

A median breakaway-cable-terminal (MBCT) design was presented in the 1977 AASHTO Design Manual (1), but that design was not commonly used. The typical MBCT involved a combination of two single BCT's. An example is that used in Kentucky (Figure 10). Another example of MBCT design is that used in Colorado (Figure 11). There was no uniformity in the designs used for MBCT-type end treatments. Depending upon median width, typical BCT terminal posts were used with various flares and offset distances.

The turned-down designs typically involved treatments similar to that for roadside guardrail. The two parallel rails may be turned down and anchored beside each other without an offset or they may be turned down independently with different flares and offset distances. An example is shown in Figure 12.

Treatments similar to the "bullnose" configuration used in Minnesota (Figure 13) were used by a few states. That treatment connected two lines of guardrail by means of a loop nose.

Another design involved using two cables to connect two parallel guardrails to a buried concrete anchor. This has been called a double anchor system. A buffer end was used to connect the two guardrails.

Two states used an earth mound in the median. Designs in which the guardrail end was flared and anchored into the earth mound were used. Protection using only the earth mound around median bridge piers was also specified.

GUIDELINES

A listing of guidelines used by the states for determining the end treatment to use for roadside steel-beam guardrail is given in Table 7. Most guidelines given are general in nature and only specify types of end treatments that are acceptable.

Several states mentioned that the availability of an adequate shoulder would determine whether the BCT treatment could be used. Speed, volume, and highway type were listed in a few guidelines.

CONCLUSIONS

Generally, the preferred method to use to end roadside steel-beam guardrail is to bury the end in a cut slope. However, roadway geometrics prevent this in most instances. When the end cannot be buried, either a BCT or turned-down end treatment is generally used. While the BCT is used most often in that instance, some states use both the BCT and the turned-down treatment, while other states use only the turned-down treatment.

The BCT treatments used in various states generally conform to that contained in the 1977 AASHTO Design Guide (2). There are differences in specifications used for the turned-down end treatments. However, the major features such as length over which the rail is twisted down and anchored are similar from state to state.

RECOMMENDATIONS

(Guardrail End Treatments in Kentucky)

Whenever possible, the approach end of roadside steel-beam guardrail should be buried in a cut slope or anchored into a rock cut using current Kentucky specifications. When those end treatments cannot be used, either the BCT or turned-down treatment should be used. The BCT end treatment should be used only when a 4-foot flare can be obtained with a 10:1 slope in advance and a sufficient recovery area, not exceeding a 3:1 slope, behind. The first nonbreakaway post (downstream...
from the terminal posts) should be placed at least 50 feet from the beginning of the point of need. Those requirements generally will mean the BCT treatment will be installed only on new construction or on reconstruction projects where geometrics permit. The BCT specifications currently used in Kentucky should be continue to be used.

Other end treatments should be constructed with a turned-down end design shown in Figure 14. That design consists of a total end-treatment length of 50 feet. The rail should be twisted 90 degrees and anchored over the last 25 feet with no posts in that section of rail. The first two guardrail post spacings should be 12.5 feet followed by posts at the regular 6.25-foot spacing. The first two posts should be a type that will break during an end impact. This could be accomplished by using either wood posts, or steel posts such as the steel weak posts detailed in AASHTO's "Guide for Selecting, Locating, and Designing Traffic Barriers" (2). Also, the connection between these two posts and the guardrail should be such that the guardrail would separate from the post during an end impact. This could be accomplished by using small diameter bolts to connect the guardrail and these posts with no blockout between the guardrail and post. The end should be offset, when possible, up to 4 feet from the line of guardrail.

Presented in Table 8 is a summary of guidelines for guardrail end treatment usage. Included are guidelines for new construction, reconstruction (when guardrail upgrading is included in the reconstruction project), and maintenance repair installations.

It should be noted that the recommendations were based primarily on current end treatment usage in other states. However, comments on performance of various types of end treatments were included in some responses and four states were contacted to request additional information concerning their experience with turned-down end treatments. In addition, field performance of BCT end treatments in Kentucky is being monitored and will be reported later in another ongoing phase of this research study. Results of that accident analysis may indicate whether the BCT end treatment is performing properly when adequate geometrics exist.

REFERENCES

## Table 1. Approach End Treatments Used for Roadside Steel-Beam Guardrail (excluding burying end in cut slope)

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**Note:** Earth Mound - Earth Mound, Flared, Not Anchored
TABLE 2. SUMMARY OF BCT SPECIFICATIONS

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a Spacing of posts same as 1977 AASHTO Guide.
b Alaska has an alternate design with a 5-foot offset over a flare distance of 62.5 feet. Both wood and steel were used for approach and terminal posts. Post spacing was 12.5 feet.
c Spacing for both wood and steel posts; 6.25 feet.
d Post spacing for approach end section was 3 feet, 1-1/2 inches.
e Spacing for both wood and steel approach posts same as steel post spacing in 1977 AASHTO Guide.
f Flare was over a 100-foot radius end section to achieve a 3-foot or 4-foot offset.
g When flare offset was 4 feet or greater, the 25-foot rail element at end of flare was not required. When a minimum flare offset of 4 feet cannot be provided, a 25-foot rail element was used and guardrail was flared as much as field conditions permit.
h Flare length increased from 50 feet for a 4-foot offset to 112.5 feet for an 8-foot offset.
i Offset distance was not specified for 37.5-foot flare. Offset from edge of shoulder was 5 feet for 100-foot flare.
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<th>END TREATMENT DISTANCE PRIOR TO TWIST (FEET)</th>
<th>DISTANCE FROM LAST POST TO END (FEET)</th>
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a End anchor was buried along with approximately one half of the twisted rod.
b Rail was not twisted but slanted into ground.
c Weakened connection between guardrail and first five posts.
d Offset distance varied and was a function of type of guardrail (W-Section or Thrie Beam) and area where guardrail terminates (vertical curb, sloped edging, or concrete berm). The range of offset distance is from 5.8 to 8.1 feet.
e Specifications were for typical steel weak post end treatment.
f First eight wood posts had two inch holes drilled in the eight inch side. Guardrail not bolted to the first eight posts.
<table>
<thead>
<tr>
<th>STATE</th>
<th>BURIED-IN-CUT-SLOPE</th>
<th>ROCK CUT</th>
<th>EARTH MOUND</th>
<th>FLARED, NONBREAKAWAY</th>
<th>DOWNSTREAM (TRAILING END)</th>
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TABLE 7. GUIDELINES FOR END TREATMENT TO USE FOR ROADSIDE STEEL-BEAM GUARDRAIL

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<thead>
<tr>
<th>STATE</th>
<th>GUIDELINES</th>
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<tbody>
<tr>
<td>Alaska</td>
<td>On all new construction and reconstruction, BCT used. Turned-down end standard. Bury end into cut slope where possible. BCT used on approach end where vehicle breaking through end has safe place to go.</td>
</tr>
<tr>
<td>Arkansas</td>
<td>Bury end into cut slope where possible. BCT used on approach end where vehicle breaking through end has safe place to go.</td>
</tr>
<tr>
<td>California</td>
<td>Turned-down treatment used. BCT standard. Prefer to bury end in cut slope or earth mound. Discourage use of BCT wherever recommended flare cannot be installed.</td>
</tr>
<tr>
<td>Connecticut</td>
<td>Turned-down treatment used. BCT standard. Prefer to bury end in cut slope or earth mound; otherwise, use BCT.</td>
</tr>
<tr>
<td>Georgia</td>
<td>BCT standard. Prefer to bury end in cut slope or earth mound; otherwise, use BCT.</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Bury end into cut slope or earth mound. Discourage use of BCT wherever recommended flare cannot be installed.</td>
</tr>
<tr>
<td>Idaho</td>
<td>Bury end into cut slope or earth mound; otherwise, use BCT.</td>
</tr>
<tr>
<td>Illinois</td>
<td>BCT only used where roadway section can accommodate the mandatory 4-foot flare and 10:1 slopes.</td>
</tr>
<tr>
<td>Indiana</td>
<td>BCT only used where roadway section can accommodate the mandatory 4-foot flare and 10:1 slopes.</td>
</tr>
<tr>
<td>Iowa</td>
<td>BCT standard. Offset and flare depend on roadway geometries.</td>
</tr>
<tr>
<td>Kansas</td>
<td>BCT standard. Offset and flare depend on roadway geometries.</td>
</tr>
<tr>
<td>Kentucky</td>
<td>Prefer to bury end in cut slope; otherwise, use BCT. BCT used for new construction and overlay projects.</td>
</tr>
<tr>
<td>Louisiana</td>
<td>Bury end into cut slope or earth mound. Flared nonbreakaway end treatment used on primary and secondary two-lane highways.</td>
</tr>
<tr>
<td>Maine</td>
<td>Turned-down treatment used on new construction where geometries permit. Where slopes not constructed sufficiently for turned-down treatment, BCT used. Flared nonbreakaway end treatment used on primary and secondary two-lane highways.</td>
</tr>
<tr>
<td>Maryland</td>
<td>Use either buried-in-cut-slope or turned-down treatments.</td>
</tr>
<tr>
<td>Michigan</td>
<td>BCT standard. Offset and flare depend on roadway geometries.</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Turned-down end used unless space limited, then use BCT. Acceptable treatments include BCT and buried-in-cut-slope treatments.</td>
</tr>
<tr>
<td>Mississippi</td>
<td>Turned-down end standard.</td>
</tr>
<tr>
<td>Missouri</td>
<td>Turned-down end standard.</td>
</tr>
<tr>
<td>Montana</td>
<td>Prefer to bury end in cut slope, otherwise use BCT. Use BCT for new construction and resurfacing projects where shoulders can be widened. Normally use turned-down end treatment for resurfacing projects.</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Prefer to bury end in cut slope, otherwise use BCT. Use BCT for new construction and resurfacing projects where shoulders can be widened. Normally use turned-down end treatment for resurfacing projects.</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>Prefer to bury end in cut slope, otherwise use BCT.</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Prefer to bury end in cut slope, otherwise use BCT. BCT generally used except turned-down end used for highways with less than 1,000 ADT or design speed less than 50 mph when shoulder width will not allow standard flare.</td>
</tr>
<tr>
<td>Ohio</td>
<td>Prefer to bury end in cut slope. For strong post system, use BCT otherwise unless necessary offset and slope is not present, then use turned-down end.</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>Turned-down end standard.</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Turned-down end standard.</td>
</tr>
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Table 7 (continued)

<table>
<thead>
<tr>
<th>State</th>
<th>Recommendations</th>
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</thead>
<tbody>
<tr>
<td>Rhode Island</td>
<td>For weak post system, use turned-down end when end cannot be buried in cut slope. Prefer to bury end in cut slope or turn-down end, otherwise use BCT.</td>
</tr>
<tr>
<td>South Dakota</td>
<td>BCT standard.</td>
</tr>
<tr>
<td>Tennessee</td>
<td>Embankments provided for BCT flare and offset when possible. Damaged section of older guardrail generally replaced in-kind.</td>
</tr>
<tr>
<td>Texas</td>
<td>Turned-down end standard.</td>
</tr>
<tr>
<td>Utah</td>
<td>Turned-down end standard.</td>
</tr>
<tr>
<td>Vermont</td>
<td>BCT used on projects having design speeds greater than 40 mph. &quot;Flared nonbreakaway&quot; end used on projects having design speed of 40 mph or less. Turned-down end used on exit end where two-way traffic would be required occasionally during maintenance or emergency conditions.</td>
</tr>
<tr>
<td>Virginia</td>
<td>For strong post system, prefer to bury end in cut slope, otherwise use BCT. For weak post system, use turned-down end.</td>
</tr>
<tr>
<td>Washington</td>
<td>Prefer to bury end in cut slope, otherwise use BCT. Use cut slope or BCT on federal-aid projects. On state projects, use BCT, cut-slope, or &quot;flared not anchored&quot; end, depending on design speed and volume.</td>
</tr>
<tr>
<td>West Virginia</td>
<td>Use &quot;flared not anchored&quot; end when design speed less than 50 mph. Use BCT on cut slope treatment when design speed is 50 mph or greater and design year AADT is 400 or above.</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Turned-down end used except at driveways or minor sideroads where BCT is used.</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Prefer to bury end in cut slope, otherwise usually use BCT. Use modified turned-down end on some upgrading projects.</td>
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**TABLE 8. GUIDELINES FOR GUARDRAIL END TREATMENT USAGE**

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<thead>
<tr>
<th>TYPE OF INSTALLATION</th>
<th>PRIORITY</th>
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<tbody>
<tr>
<td>New Construction</td>
<td>1. Buried-in-Cut-Slope or Anchored into Rock Cut Preferred if Conditions Permit.* &lt;br&gt;2. Use BCT.</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>1. Buried-in-Cut-Slope or Anchored into Rock Cut Preferred if Conditions Permit.* &lt;br&gt;2. Use BCT if Geometrics Permit.** &lt;br&gt;3. If Geometrics Preclude Use of BCT, Use Turned-Down End.</td>
</tr>
<tr>
<td>Maintenance Repair</td>
<td>1. Buried-in-Cut-Slope or Anchored into Rock Cut Preferred if Conditions Permit.*** &lt;br&gt;2. Use BCT if Replacing Properly Installed BCT.** &lt;br&gt;3. Use Turned-Down End.</td>
</tr>
</tbody>
</table>

* Guardrail should not be extended more than 200 feet longitudinally from point of need, not including flare length, to reach a cut slope (exceptions may be warranted due to field conditions).

** BCT end treatment used only when a four-foot flare can be obtained with a 10:1 slope in advance and a sufficient recovery area, not exceeding a 3:1 slope, behind. The first nonbreakaway post downstream from the terminal posts) should be placed at least 50 feet upstream from the beginning of the point of need.

*** Guardrail should not be extended more than 50 feet longitudinally from point of need, not including flare length, to reach a cut slope (exceptions may be warranted due to field conditions).
Figure 1. Standard Flare for Wood- and Steel-Post Design of the Breakaway Cable Terminal End Treatment

Wood-Post Design (Idaho)

- Use single W-beam section
- Curved terminal
- Use single W-beam section

Steel-Post Design (Virginia)

- Use single W-beam section
- Curved terminal
- Use single W-beam section

Plan

- Provide all washers on post 1. Omit flat plate washers on posts 2 through 7.

6"x8" end wood post

6"x8"x14" or 8"x8"x14" blocks

6"x8" or 8"x8" wood posts and 6"x8"x14" or 8"x8"x14" blocks

24" dia. concrete footings or steel tubes

6"x8" wood post

Back of rail for straight section

6 spaces at 6'-3"=37'-6" parabola

NOTE: Provide all washers on post 1. Omit flat plate washers on posts 2 through 7.
Figure 2. BCT Terminal Post Assembly Detail Using Wood Posts (Virginia)

- Terminal Connector
- 6"x8"x5'-4" Wood Post
- 5/8 Carriage bolt w/hex nut and cut washer
- Cable Assembly
- Corrugated w/hexnut and cut washer
- 24" Dia. concrete footing (Two posts only)
- 11" Radius Terminal Section
- (For details see sheet 1 of 4)

PLAN

A

6'-3"

See Detail B

Anchor Plate

5/8 x 10" bolt

6"

12"

2 3/8" dia. hole

3.5" x 2.5"

3" x 0.5" Welded wire fabric cylinder

ELEVATION

TERMINAL POST ASSEMBLY

End Post

6" x 8" x 5'-4"

2" Std. Galv Pipe
(2.375" OD)

Cut Washer

Top of Footing

Cable Assembly

4"

End Post

6" x 8" x 5'-4"

6" x 8" x 3/8" Plate

Cut Washer

DETAIL B
Figure 3. Turned-Down End Treatment (Minnesota)
Figure 4. Turned-Down End Treatment (New Hampshire)

**Use:** Wherever Beam Guard Rail is warranted

**Elevation**

**Terminal Unit Type F**

Scale: 1/8" = 1'-0"

Item No. 521.76. Steel Post, Beam Guard Rail (Terminal Unit Type F)

Paid: Lump sum, including end section and anchor.

Use: At beginning or end of section for warranted guard rail when terminating in a fill section or an excavation section with a +1% grade slope (do not use within warrant limits).

Figure 5. Turned-Down End Treatment (Maryland)

**Plan**

Limit of Linear Foot Measurement of Payment for "Guard Rail W Beam" - End Flare

Limit of Each Measurement of Payment for "Guard Rail W Beam" - End Flare

**Elevation**

1'-3" Note: Offset to face of rail
Figure 6. Buried-in-Cut-Slope End Treatment Design (Wyoming)

END ANCHORAGE TYPE IV

ANCHOR BLOCK

ANCHOR

TOP VIEW

2'-4"

ANCHOR SHALL BE CLASS B CONCRETE AND SHALL BE PRECAST OR CAST IN PLACE.

FRONT VIEW

END PAY LENGTH OF GUARD RAIL

PC.

DITCH BOTTOM

ROUGH POST (TYP)

ROUGH POST (TYP)

ADJUST POSTS TO FIT EXISTING CONDITIONS

6" x 8" x 1'-2"

ANCHOR BLOCK

GAL. BOLTS (3" THREADS)
Figure 7. Downstream Terminal (Buried Anchor) (Tennessee)
Figure 8. Downstream Terminal (Anchor in Last Post) (North Carolina)

Figure 9. End Treatment for Cable Guardrail (New York)
Figure 10. Median Breakaway Cable Terminal Design (Kentucky)

PLAN:

ELEVATION:
Figure 11. Median Breakaway Cable Terminal Design (Colorado)
Figure 12. Median Turned-Down End Treatment (Arkansas)

Figure 13. Median Guardrail End Treatment Used in Minnesota
(Nose Detail Five-Foot Radius)
Figure 14. Proposed Turned-Down End Treatment

**PLAN**

**ELEVATION**

Notes:

1. D of 4 feet is desirable. The offset is to be made as large as possible up to a 4-foot maximum.
2. Use either wood or steel weak posts for Posts 1 and 2.
3. Use small diameter bolts to connect Posts 1 and 2 to guardrail.
Dear Mr. ______:

The Transportation Research Program is conducting a research study for the Kentucky Department of Highways titled "Evaluation of Highway Safety Barriers." One of the objectives of this study is to develop warrants and guidelines to assist engineers in deciding when and where various types of guardrail end treatments should be installed. Major problems presently exist when attempting to replace older end treatments with the breakaway-cable-terminal (BCT). Many of these problems are associated with insufficient space to permit proper flaring of the BCT end treatment.

It would be of significant value to know if your state has developed warrants and/or guidelines to use when determining the type of end treatment needed for a given situation considering factors such as volume, geometrics, operational characteristics, etc. Also, it would be very beneficial to our study to learn what the standard end treatments are in your state. Therefore, we would greatly appreciate any material (including standard drawings) you could provide concerning guardrail end-treatment standards and their related warrants used in your state.

We plan to publish a summary of the standards and warrants used across the nation for guardrail end treatments. We will send you a copy of this publication if you desire.

Thank you for your cooperation.

Sincerely,

Jerry G. Pigman
Research Engineer
APPENDIX B

SUMMARY OF SURVEY RESPONSES
ALABAMA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide for standard hazard installation. Standards for BCT are different for installations at bridges and installations when the hazard is located within 4 feet of shoulder.
   b) Shoulder widening is required when the area in front of BCT slopes more than 10:1.
   c) Standards are given for both wood and steel breakaway posts.
   d) Wood-post dimensions are 5 1/2 by 7 1/2 inches.
   e) No back-up plate and no washers are to be used under bolt heads.
   f) Breakaway wood posts are inserted in a steel tube, which is used rather than concrete footing.
   g) A diaphragm (optional) is used inside the terminal end shoe.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   Downstream End Treatment
   The end treatment is anchored into a buried concrete footing. The concrete anchor has a minimum diameter of 1.5 feet and a depth of 5 feet. The center of the anchor is 5.5 feet downstream from the last post. A cable and rod connects the concrete anchor to an anchor plate on the guardrail. This anchor plate begins 1 foot from the center of the second post. This is a typical design used by many states for their downstream end treatment.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   No use indicated in survey response.

C. MEDIAN-BARRIER END TREATMENT
   No information provided.

D. GUIDELINES
   None given for end treatments.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as the 1977 AASHTO Guide for standard BCT.
   b) Standard BCT uses both wood and steel posts. Standard wood BCT uses 6- by 8-inch posts.
   c) Alternative transition and terminal section uses a minimum 6.5-foot length; uses minimum 5-foot offset, and uses 12.5:1 straight flare.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   Buried-in-Cut-Slope
   Includes following: concrete anchor, normal rail height, and 12:1 flare.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

1. BOX BEAM
   Terminal end section has a radius of 360 feet, 6-foot post spacings, and an arc length at 72 feet.

2. CABLE
   Terminal end is 36 feet in length, 6-foot minimum offset, and no posts are used in the last 18 feet.

C. MEDIAN-BARRIER END TREATMENTS

1. Median steel-beam guardrail is used with both wood and steel posts. Nonbreakaway is used for both wood and steel post design.

2. A Median Breakaway Cable Terminal (MBCT) is used with wood posts. The beam guardrails meet at the end post; however, they are separated at the second post back from end.

3. In the box-beam median end treatment, the rail slopes to ground level over an 18-foot section and the end is anchored in concrete.

D. GUIDELINES

On all new construction and reconstruction, BCT's are used on leading and trailing ends, except on divided and one-way facilities.
ARKANSAS

A. ROADSIDE STEEL BEAM

1. BCT
   No use indicated in survey response.

2. TURNED-DOWN
   a) End section is twisted 90 degrees and turned down over last 24 feet, 9 3/4 inches.
   b) One post is spaced 18 feet, 6 3/4 inches from the end, which is anchored in concrete. Steel posts are used.
   c) There is no offset.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END-TREATMENTS

   Two parallel rails are turned down. Each twisted 90 degrees over a distance of 24 feet, 9 3/4 inches with the last post 18 feet, 6 3/4 inches from end.

D. GUIDELINES

   Turned-down end is standard treatment.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Design is same as 1977 AASHTO Guide.
   b) Both wood and steel posts are used. Wood posts are 6 inches by 8 inches.
   c) Rectangular plate washers are omitted under post bolt heads for Posts 2 through 8.

2. TURNED-DOWN
   No use indicated in survey response.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

   MBCT similar to 1977 AASHTO Guide is used. A sheet metal nose is used in place of the 55-gallon steel drum as shown in the AASHTO Guide.

D. GUIDELINES
   None given.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Use 6- by 8-inch wood posts for two breakaway posts.
   b) Use either wood or steel posts for approach to two breakaway posts. Post spacing of 6 feet, 3 inches for both steel and wood posts on a 37-foot, 6-inch parabola are used.
   c) Use a 4-foot typical or ideal and 2-foot minimum offset distance. The 2-foot minimum distance allows engineering judgment to be applied in restricted situations.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Nonbreakaway Cable
      Used where breakaway design is not desirable. Both steel and wood posts are used. End section is attached to anchor by cable and anchor rod. Reinforced concrete anchor post is 2 inches below surface and anchor rod is attached 1 foot below surface. Anchor post has a 1.5 foot diameter and is 5 feet long. Anchor is placed in ground 5.5 feet (variable) from last post. Terminal end shoe is placed at end of guardrail.
   b) Buried-in-Cut-Slope
      Involves a buried post anchor in which the guardrail is attached to a backup plate and steel post placed in a concrete anchor.
   c) Downstream Terminal
      Rail is cable anchored into a buried concrete anchor.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

Various flares are used depending upon type of obstacle and median width. Use double-anchor cable assembly (nonbreakaway) with a return section that is a terminal end shoe connecting the two guardrails. Use both wood and steel posts.

D. GUIDELINES

BCT is used on the approach ends of all guardrail installations where a vehicle breaking through the end has a safe place to go. Alternative end anchorages are provided for other situations. A nonbreakaway cable is provided for intermediate anchorages and situations where the breakaway design is not desirable. Also, buried post anchor is provided for situations where it is possible to bury the approach end of the guardrail into a cut slope.
COLORADO

A. ROADSIDE STEEL BEAM

1. BCT
   a) Use a 75-foot arc with a wood-post spacing of 6 feet, 3 inches. Offset of 4 feet.
   b) Last 25 feet of W-Beam rail without splices.
   c) Do not use washers under post bolt heads on Posts 2 through 8.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Buried-in-Cut-Slope
      The rail extends into the slope and a 2- by 2- by 3-foot concrete anchor block buried in the slope.
   b) Downstream Terminal
      Cable anchored into buried concrete. Anchor buried downstream from the last post.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No use indicated in survey response.

C. MEDIAN-BARRIER END TREATMENTS

A nose design that is weakened to allow a crash distance similar to the single BCT end-treatment is used. The nose post (all posts are wood) and both sets of the first three behind-the-nose posts are slit to weaken the end treatment. The cable connection is between the first and second posts behind the nose post.

D. GUIDELINES

None given.
A. ROADSIDE STEEL BEAM

1. BCT
   Use not indicated in survey response.

2. TURNED-DOWN
   Two types of metal beam are specified (Type R-I and R-B) with R-I preferred. For each type of metal beam, two types of end treatment are given with Type I preferred in each case.
   a) Type I (use with metal beam Type R-I) -- End section twisted 90 degrees and anchored over a distance of 27 feet, 1 inch. End is not offset.
   b) Type I (use with metal beam Type R-B) -- Metal Beam (Type R-B) End section twisted 90 degrees and anchored over a distance of 23 feet, 6 inches with half of this section underground. No posts in the twisted section. The end is offset 4 feet, 6 inches. An additional four posts spaced at 6 feet, 3 inches over a total distance of 25 feet are flared at a slope of 25:1. The last post is offset 1 foot.
   c) Type 2 (use with both metal beam types) -- End section twisted 90 degrees and anchored over a distance of 11 feet with last post at this point. End is offset 2 feet, 4 inches.

3. OTHER
   a) Buried-in-Cut-Slope
      Last line post is at top of slope. Rail extends 23 feet, 6 inches to concrete anchor. Rail deflects 4 to 6 feet from line of guardrail to end of rail. Three-inch minimum earth cover over top of rail. End of rail is on top of concrete anchor and bolted.
   b) Rock Cut
      Rail attached directly to rock cut and non-shrink grout with anchor bolts. Bolts placed minimum of 2 inches into rock. Center of attachment of rail to cut approximately 23 feet, 6 inches from first line post.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

CABLE
   This is the preferred type of railing. Two end anchorages are given, Type I preferred.
   Type I -- Approach or terminal section length of 42 feet. Last post 18 feet from anchor. Four additional posts at 6-foot spacings. End anchorage buried and offset 4 feet, 3 inches.
   Type II -- End anchorage of 24 feet with last post 8 feet from anchor. Not offset.

C. MEDIAN-BARRIER END TREATMENTS

Median metal-beam treatment involves a total section length of 27
feet, 1 inch from the last posts to the anchor over which both rails are 90 degrees. The two rails are attached at a distance of 13 feet, 6 1/2 inches from end.

D. GUIDELINES

1. Cable -- Type I is preferred. Type II, which is shorter than Type I, should be used only where narrow openings such as at driveways must be left in the run of railing.

2. Metal Beams (R-I and R-B) -- End-anchorage Type I is desired. Type II to be used only when narrow openings are required along the guardrail and then only where appropriate grading for Type I would not be practicable.
DELAWARE

A. ROADSIDE STEEL BEAM

1. BCT
   a) Specifications are similar to those in 1977 AASHTO Guide, except length of parabola is 37 feet, 2 5/8 inches instead of 37 feet, 6 inches.
   b) Spacing of posts and offset distance are same as AASHTO Guide.
   c) Either steel or wood posts may be used and wood posts are 6 by 8 inches.

2. TURNED-DOWN
   a) Guardrail is turned down and twisted over the last 25 feet.
   b) Posts are spaced at 6 feet, 3 inches with no posts in the last 12 feet, 6 inches.
   c) Length of taper is 62 feet, 6 inches and offset is 4 feet for shoulder installation.
   d) Length of taper is 150 feet and offset is 10 feet for median installation.
   e) End section is anchored in concrete footing flush with surface.

3. OTHER
   Use not indicated in survey response.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

CABLE
   a) End post is offset 2 feet, 6 inches and taper is over last 25 feet.
   b) Posts are spaced at 12 feet, 6 inches.
   c) Anchor rod is tied to cast-in-place concrete footing.
   d) Wood posts with 8-inch diameter are used.

C. MEDIAN-BARRIER END TREATMENT

Turned-down end treatment is used in median with 150-foot taper and 10 foot offset.

D. GUIDELINES

None indicated.
FLORIDA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are same as 1977 AASHTO Guide.
   b) Wood posts with dimensions of 8 by 8 inches are used.
   c) A 5-foot long steel tube, in which to inset the two breakaway posts, is used.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   Trailing (Downstream) End
   Cable anchored into concrete anchor block. Center of concrete anchor block is spaced 4 feet, 9 inches from last post.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

   Typical trailing -- End anchorage is used for medians. Buffer end shoe is attached to approach end section. Concrete anchor block is 30 by 30 inches. Back-to-back steel-beam rail is tied into end post with wood blockouts. Taper rate toward end section for design speeds under 50 mph is 10:1. Taper rate for speeds 50 mph and greater is 15:1.

D. GUIDELINES

   1. For medians widths 50 feet or greater, a BCT without parabolic curve is used.
   2. For median widths less than 50 feet, taper rate toward terminal section is 10:1 for design speeds under 50 mph and 15:1 for design speeds 50 mph and greater.
GEORGIA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are same as 1977 AASHTO Guide.
   b) Use both steel and wood (6 by 8 inches) posts.
   c) Alternative of placing wood breakaway posts in preformed concrete footing or steel tube.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Trailing-End Anchorage (One Way Highway)
      Involves anchoring the guardrail to a precast deadman placed about 15 feet, 6 inches from last post. Curved section placed on end of guardrail.
   b) Trailing-End Anchorage (Installations Outside Clear-Zone on Two-Way Highways)
      Consists of a curved 12-foot, 6-inch section with a 30-foot radius in addition to the typical trailing-end anchorage.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENTS

No information provided.

D. GUIDELINES

BCT is standard at the approach end of all guardrail installations.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide for standard BCT.
   b) Use steel posts.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   a) Buried-in-Cut-Slope
      Involves flaring the guardrail with a 15:1 flare into the cut slope. The guardrail is anchored into a 3- by 3- by 3-foot concrete anchor block buried in cut section. A special end shoe is used on the guardrail. A 25-foot parabola is used to transition the guardrail to the 10:1 flare. The end of the guardrail is 7 feet from the edge of the shoulder.
   
   b) Earth Mound
      Used when the recommended flare for the BCT cannot be installed or there is no cut slope available. The guardrail is flare with a 15:1 flare into an earth mound with the guardrail 2 feet, 8 inches from the edge of the shoulder. The earth mound has a maximum height of 3 feet with a 4:1 slope on the end facing approach traffic and a 2:1 slope on the other sides. The guardrail is anchored by a cable and rod into a concrete anchor block. A 25-foot parabola is used to transition the guardrail to the 15:1 flare.

   c) Trailing Guardrail-End
      On one- and two-way roadways, both cut slopes and earth mounds are used to bury the end. The details are similar to those for the approach end except that a 10:1 flare is used rather than the 15:1 flare.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END TREATMENT

   The G.R.E.A.T. system is used for narrow median end treatments. An earth mound is also used. The configuration of the mound is like that used for a single guardrail installation on the shoulder. The edge of the mound is a 2-foot minimum distance from the shoulder.

D. GUIDELINES

   Discourage the use of the BCT whenever the recommended flare cannot be installed. Most end treatments are buried in cuts or earth mounds.
IDAHO

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use 6- by 8-inch wood posts.
   c) Use either steel tube or preformed concrete footing to receive the breakaway parts.
   d) The 4-foot flare is an essential feature of the terminal. Flares other than the standard 4-foot flare may be used where the guardrail is flared across a highway median to protect vehicles from running into the gap between two bridges.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   a) Buried-in-Cut-Slope
      Involves anchoring the guardrail into a special concrete end post with the top of rail to be buried below ground level. The guardrail is to maintain standard height across any ditch. The end post is 5 feet in depth with the other dimensions 1 foot, 6 inches by 1 foot, 6 inches.

   b) Earth Mound
      Protection for roadside guardrail is given. The mound has 4:1 side slopes with an approach length of 120 feet with 50:1 slope to the top of the mound and a 12:1 back slope, giving a total length of 155 feet. The mound begins a minimum of 6 feet from the shoulder with the top of the mound a minimum of 18 feet from the shoulder.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

   Earth-mound protection for median columns is noted. The mound has 3:1 side slopes with the top 5 feet, 6 inches above the roadway elevation. The approach slope is 25:1, reaching the maximum height 30 feet in advance of the median columns.

D. GUIDELINES

   The preferred guardrail terminal treatment is to curve the rail into a cut slope or earth mound and bury the end. The BCT is used for metal rail not buried in a cut slope or earth mound.
ILLINOIS

A. ROADSIDE STEEL BEAM

1. BCT
   a) When the 4-foot flare is used, the 37-foot, 6-inch parabola and typical offsets are used. A 10:1 slope in advance of the end is noted. The 4-foot offset is obtained over a 50-foot minimum, 100-foot desirable distance.
   b) The flare can be reduced to a minimum of 1 foot. When this 1-foot flare is used, only the two breakaway posts are offset with the second post offset 3 inches. Other post spacings are the same as for the typical 4-foot flare.
   c) Both steel and 6- by 8-inch wood posts are used.
   d) Tubular steel foundations are used.
   e) Diaphragms are used in the nosepiece to reduce the potential for spearing and minor damage to the nosepiece caused by nuisance hits.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated.

C. MEDIAN-BARRIER END TREATMENTS

No information provided.

D. GUIDELINES

The BCT is the standard end treatment for the approach ends of all guardrails. Since the 4-foot flare cannot be obtained on all roadways, the flare can be reduced to a minimum of 1 foot with the stipulation that as much flare as the roadway geometrics allow be provided.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Steel posts are used.
   c) Two 14-gage steel diaphragms are required in the terminal section.
   d) Slope in advance of BCT is 10:1 or flatter.

2. TURNED-DOWN
   a) The total length of this end treatment is 31 feet, 3 inches.
   b) The rail is not twisted but slanted into the ground with no offset. A 25-foot section of rail is connected to the longitudinal section by a splice plate and to a concrete anchor by a steel plate. This steel plate is 4 feet, 10 3/4 inches in length and is entirely underground.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

STEEL TUBE AND ALUMINUM
The end is buried over a length of 40 feet. A maximum post spacing of 13 feet, 4 inches is specified. The end treatment is attached to the longitudinal rail with a rail splice and slanted into the ground with no offset. The top rail and post are completely buried at the end of the treatment. The top rail of the aluminum guardrail end treatment may be a continuous section of rail or two sections of rail with a rail splice.

C. MEDIAN-BARRIER END TREATMENTS

No information provided.

D. GUIDELINES

Buried end treatments are used for all aluminum- and steel-tube rail installations. For steel-beam rail, both buried and BCT end treatments are used. The BCT is used only at locations where the roadway section can accommodate the mandatory 4-foot offset and 10:1 slopes.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Wood posts (6 by 8 inches) are used as breakaway posts.
   c) Breakaway posts installed with 3/4-inch polystyrene foam on two sides (8-inch side of approach traffic, 6-inch side nearest roadway) before placing concrete footing.
   d) Plate washers omitted for first six posts.

2. TURNED-DOWN
   No use indicated.

3. OTHER
   Downstream Terminal
   Used only when it is shielded from approach traffic. The terminal section is anchored into concrete with a cable and anchor rod.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Cable guardrail was indicated as used but no details concerning end treatment were given.

C. MEDIAN-BARRIER END TREATMENT

The Minnesota "bullet-nose" is an adaption for median use. It is termed a breakaway end anchorage. Three wood posts are placed at a 5-foot radius using a bent 12-foot, 6-inch guardrail section to form the nose. The nose post is 6 by 8 inches while the posts on either side are 8 by 8 inches. These three posts are installed in concrete footings with 3/4-inch polystyrene foam on two sides. Cable assemblies are installed on the two 6- by 8-inch posts and anchored on the downstream guardrail before the next regular post.

D. GUIDELINES

The BCT is the only end treatment employed where the terminal is exposed to oncoming traffic. The Minnesota "bullet-nose" is an adaption for median use.
KANSAS

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use both wood (6- by 8-inch) and steel breakaway posts.
   c) Wood breakaway posts are inserted in steel tube.
   d) Steel breakaway posts use 2- by 3-foot concrete footing.

2. TURNED-DOWN
   a) End treatment has a total length of 50 feet.
   b) There is no post in the last 25 feet with the rail twisted 90 degrees and anchored with an offset distance of 2 feet.
   c) Last five posts are spaced at 6 feet, 3 inches with the guardrail attached to these posts with bent straps. These five posts are 6-foot long wood posts with 6-by 8-inch dimensions.

3. OTHER

   Non-Breakaway-Terminal
   Specified where there is no opposing traffic within the clear zone distance. This terminal involves a 25-foot section of rail flared 2 feet. A 6-foot, 3-inch post spacing is used.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

   No information provided.

D. GUIDELINES

   The BCT is used on all new construction and reconstruction of high-volume roads. The turned down terminal is used on roads with restricted right of way with no room for widening for the 4-foot offset the BCT requires.
KENTUCKY

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Wood posts (6 by 8 inches) are used.
   c) Posts are placed in concrete footing with sand or 1/4-inch polystyrene foam sheeting around the post.

2. TURNED-DOWN
   No use indicated.

3. OTHER
   a) Buried-in-Cut-Slope
      Involves anchoring the end post (which is buried) into a concrete anchor. All post spacings are 6 feet, 3 inches. The end post is buried a minimum of 1 foot. The distance from the shoulder to the guardrail end varies from 2 to 6 feet as a function of front and back slope.

      b) Downstream Terminal
         Uses a nonbreakaway design in which the guardrail is anchored to a concrete footing with a cable and anchor rod (cable anchored type).

      c) Rock Cut
         The end treatment at the downstream terminal is used for the approach end when there is not an adequate recovery zone. When an adequate recovery zone exists, the BCT is used.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

   A median breakaway cable terminal (MBCT) is used. A nose breakaway post is used in conjunction with one other breakaway wood post. These posts have blockouts on each side attached to guardrail. A cable assembly is attached to both guardrails and an eye bolt on the nose post. A terminal section is connected to the end of each guardrail.

D. GUIDELINES

   The buried-in-cut-slope end treatment is preferred. When it cannot be used, the BCT is used where possible. When the buried or BCT are not feasible, a cable anchored or turned down type may have to be considered.
LOUISIANA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Offset to nose of BCT is a minimum of 4 feet.
   b) Use wood (6- by 8-inch) or steel breakaway posts.
   c) A 25-foot rail is constructed in parabolic curve to end of BCT.
   d) Length of rail for terminal section is 43 feet, 9 inches, minimum width 6 feet, 3 inches added for BCT breakaway section.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   Trailing (Downstream)
   A cable is connected from the bottom of the post to the guardrail at a location close to the next-to-last post.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

No information available.

D. GUIDELINES

BCT is used for new construction and overlay projects.
MAINE

A. ROADSIDE STEEL BEAM

1. BCT
   a) Four-foot offset; 37-foot, 6-inch parabola; spacing is same for wood or steel posts (spacing for steel posts as given in 1977 AASHTO Guide).
   b) Wood breakaway post (6 by 8 inches) inserted into steel tube.

2. TURNED-DOWN
   a) Last 25 feet turned 90 degrees with last post 12 feet, 6 inches from end.
   b) Next 125 feet of guardrail flared with posts at a 6-foot, 3-inch spacing to junction with longitudinal guardrail.
   c) End offset is 17 feet from the edge of pavement. Offset is 15 feet from line of guardrail. The flare is not required for low volume highways.

3. OTHER
   Flared Nonbreakaway
   Involves flaring the end 6.61 feet from the edge of the shoulder and placing an end shoe at the end. The approach consists of 25 feet of guardrail at a 300-foot radius followed by 12.5 feet of guardrail at a 30-foot radius.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   Use not indicated.

C. MEDIAN-BARRIER END TREATMENTS

   No information provided.

D. GUIDELINES

   The turned-down end is generally used on new construction of interstate where the slopes can be constructed to accommodate this treatment. The BCT is used mainly in replacing end sections where the slopes were not constructed sufficiently for the turned-down end. The flared nonbreakaway end treatment is used generally on primary and secondary two-lane highways.
MARYLAND

A. ROADSIDE STEEL BEAM

1. BCT
   Do not use BCT.

2. TURNED-DOWN
   a) Last 25 feet of rail is twisted 90 degrees and anchored at and offset distance of 6 feet.
   b) Last post is a 6- by 8-inch wood post and there is a 12-foot, 6-inch spacing to the first steel post.
   c) Seven steel posts are spaced at 6-foot, 3-inch intervals.
   d) Total length of treatment from beginning of flare to end is 75 feet.

3. OTHER
   Buried-in-Cut-Slope
   Involves flaring the guardrail with a 200-foot radius at a constant elevation over the ditch line into the cut slope. The end post (3 feet, 4 1/2 inches in height) is underground and half of its length is embedded in a 2-foot circular concrete block that is 2 feet, 3 inches in depth. Placement of posts is to be adjusted to avoid being installed in center of ditch.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   Use blocked-out W-beam steel exclusively.

C. MEDIAN-BARRIER END TREATMENTS

1. Parallel guardrail twisted 90 degrees over a 12-foot, 6-inch distance to a median-barrier end block. Last post 6 feet, 3 inches from end.

2. Barrier end enclosure uses an earth mound with end buried in the center of the 80-foot long mound. Guardrail begins to lower from its normal height 50 feet from the guardrail end. Maximum height of mound is 2 feet.

D. GUIDELINES

   For roadside guardrail, use either a buried-in-cut-slope or turned-down end treatment. Do not use BCT.
MASSACHUSETTS

A. ROADSIDE STEEL BEAM

1. BCT
   No use indicated in survey response.

2. TURNED-DOWN
   a) Total length of terminal section is 112.5 feet.
   b) Guardrail is twisted and turned down over 37.5 feet.
   c) All posts in terminal section are spaced 6 feet, 3 inches.
   d) The offset distance varies as a function of type of guardrail (W-Section or Thrie Beam) and area where guardrail terminates (vertical curb, sloped edging, or concrete berm). The range of offset distance is from 5.8 to 8.1 feet.
   e) Both wood and steel posts may be used.

3. OTHER
   Downstream End-Treatment
   Terminal section is specified for both W-Section and Thrie Beam. End post may be anchored in concrete when typical embedment is not feasible.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated.

C. MEDIAN-BARRIER END TREATMENTS

Specifications were given for installation of highway guardrail in medians with open well between twin bridges. For this use, the length along the face of highway guardrail was 250 feet. End of terminal section was tangent over 62.5 feet. The next 37.5 feet was a circular curve and the remaining 150 feet was normal alignment. Offset distance varied from 9 inches to 10 feet, dependent upon area where guardrail terminates.

D. GUIDELINES

Turned-down end treatment is standard.
A. ROADSIDE STEEL BEAM

1. BCT
   The BCT end treatment has been used as standard since 1974. Two designs are used:
   a) When the 15:1 taper between shoulder and face of tangent rail can be obtained, the BCT is offset 3 feet on a 100-foot radius end section. Wood posts are used and spacing for the last six posts is 6 feet, 3 inches. The wood posts are 6 by 8 inches and are placed in a steel sleeve.
   b) When the 15:1 taper between shoulder and flare of tangent cannot be obtained, the BCT end must be offset at least 4 feet from the tangent line of the guardrail installation. Other features are same as noted above.

2. TURNED-DOWN
   A turned-down end treatment with posts was used as standard from 1966-1971. From 1971-1974, the standard end treatment was a turned-down type without posts.

3. OTHER
   Updating of existing blunt end treatments is accomplished by adding a curved section (50 foot-radius) of guardrail, connected to a straight section and nonbreakaway buffered section and nonbreakaway buffered end shoe. A maximum 4-foot offset is required.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENTS
   For medians greater than 55 feet, standard Michigan BCT is used. For medians 46 to 55 feet, standard Michigan BCT is used along with curled end to tie secondary end treatment to back side of guardrail.

D. GUIDELINES
   1. Michigan BCT is used as standard end treatment.
   2. When 15:1 taper between shoulder and face of guardrail tangent section can be obtained, the BCT is offset 3 feet on a 100-foot radius end section.
   3. When 15:1 taper between shoulder and face of guardrail tangent section cannot be obtained, the BCT end must be offset at least 4 feet from the tangent line of the guardrail installation.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use 6- by 8-inch wood breakaway posts in concrete footing. Posts placed in 6 1/2- by 8 1/2-inch socket with void around post filled with silica sand to within 1 inch of top with remainder caulked with an approved waterproof material. An alternate foundation uses a steel tube in which to place the wood breakaway post.
   c) Approaches to BCT should be as level as possible, preferably 10:1 or flatter.
   d) Necessary to have a clear zone directly behind the breakaway section so that a vehicle penetrating it may clear the hazard being shielded.

2. TURNED-DOWN
   a) Last 25 feet of rail twisted 90 degrees with no posts.
   b) A minimum offset of 2 feet over this 25 feet of rail.
   c) Next two posts spaced at 12 feet, 6 inches giving a total end-treatment length of 50 feet.

3. OTHER
   a) Downstream Terminal
      Involves connecting a buried concrete anchor to the guardrail using an anchor cable and rod.
   b) Buried-in-Cut-Slope
      Involves burying the guardrail end in an earth mound to the full guardrail height.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

CABLE
An end post anchored by a precast concrete bearing block is used. The end post is then connected to a buried anchor block by a turnbuckle anchor rod. The end post is offset about 9 inches back from the line posts.

C. MEDIAN-BARRIER END TREATMENTS

A 5-foot radius ("bullnose") treatment is used in gore areas and to close two lines of guardrail by means of a loop nose. A 12-foot, 6-inch guardrail section subtends an arc of about 143 degrees.

D. GUIDELINES

Use of BCT treatment is limited to installations where space is limited and a turned-down end treatment (twisted end) would be difficult to install.
MISSISSIPPI

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use 6- by 8-inch wood posts placed in either concrete footing or steel tube or use breakaway metal posts placed in concrete footing.
   c) Two diaphragms placed in buffer end section.

2. TURNED-DOWN
   Use not indicated. Investigating the possibility of using a "modified Texas twist".

3. OTHER
   a) Cable Anchorage
      Used for both metal and timber posts. A cable and rod connects the guardrail (using an anchor plate) to a buried concrete anchor.
   b) Buried in Cut Slope
      An end treatment flared and buried into a cut slope is used.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No use indicated.

C. MEDIAN-BARRIER END TREATMENTS

A breakaway-type treatment in which the two end breakaway posts are connected to two parallel guardrail using blockouts is used. A cable assembly is attached to both guardrails and an eye bolt on the nose (end) post. An end section is connected to the end of the two paralleled guardrails.

D. GUIDELINES

Acceptable guardrail end treatments include the BCT and the buried-in-cut-slope treatment.
A. ROADSIDE STEEL BEAM

1. BCT
   Have not used BCT.

2. TURNED-DOWN
   a) Last 25 feet of rail turned through 90 degrees with posts spaced 6 feet, 3 inches over the 25-foot transition.
   b) End not offset.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No use indicated.

C. MEDIAN-BARRIER END-TREATMENT

Use two parallel turned-down guardrails twisted over 25 feet with rail on either side of steel posts.

D. GUIDELINES

Turned-down type terminal section is the only type used on the approach end in the direction of traffic when installed at accessible locations on standard roadways and less than 30 feet from the roadway.
A. ROADSIDE STEEL BEAM

1. BCT
   a) A 75-foot terminal end section is specified to be used on all approach ends and on all two-lane, two-way departure ends. Twelve posts, including the two breakaway posts, are flared at a constant slope to a maximum offset of 8.5 feet.
   b) Use wood (6- by 8-inch) breakaway posts placed in a concrete footing.

2. TURNED-DOWN
   No use indicated.

3. OTHER
   Buried-in-Cut-Slope
   Involves flaring guardrail into the cut slope using 20 posts at a post spacing of 6 feet, 3 inches. Offset of last post is 28.66 feet.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

CABLE
   A driveway anchor section that involves anchoring an end post with a rod to a buried concrete anchor is used.

C. MEDIAN-BARRIER END TREATMENT

   Information not available.

D. GUIDELINES

   The slope-embedment (buried-in-cut-slope) treatment is preferable to the BCT.
NEBRASKA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use 5 1/2- by 7 1/2-inch breakaway wood posts inserted into a steel tube.
   c) Last 25 feet is one W-beam element.

2. TURNED-DOWN
   a) Last 25 feet of rail twisted 90 degrees and anchored with no posts.
   b) End offset of 6 inches.
   c) Rail element is not connected to the first five posts (6- by 6-inch wood), but rather to backup connection pieces using steel fastening straps. The purpose is to weaken the connections to allow the rail to disconnect from the posts when impacted.
   d) The total terminal section length is 50 feet.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   No use indicated.

C. MEDIAN-BARRIER END TREATMENTS
   Information not available.

D. GUIDELINES
   For new construction, when the lateral clear distance cannot be acquired, then guardrail is installed out to the desirable lateral distance with a BCT. For resurfacing projects, normally modify existing 25-foot terminal section of standard 50-foot turned-down end treatment. For resurfacing projects when a new end treatment is required and shoulders can be widened, a BCT is installed.
NEVADA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are
      the same as 1977 AASHTO Guide.
   b) Use 6- by 8-inch wood breakaway posts in concrete footing
      with one layer of 1/4-inch expanded polystyrene foam
      sheeting. Approach posts may be wood or steel.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   Buried-in-Cut-Slope
   Involves flaring the guardrail across the ditch at the standard
   guardrail height. Use a 50-foot parabola to change from the
   longitudinal barrier to the approach to the slope. Bury
   guardrail at least 6 feet into the slope and end of guardrail is
   attached to an end post that has a 3-foot minimum height. Area
   in advance of guardrail as it flares to the cut shall have a
   slope of 10:1 or flatter.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No use indicated.

C. MEDIAN-BARRIER END TREATMENT

   A median-breakaway-cable-terminal is used. The two breakaway posts
   have guardrail on each side attached to blockouts. A cable assembly
   is attached to both guardrails and an eye bolt on the nose post. A
   terminal section is connected to the end of each guardrail.

D. GUIDELINES

   None given.
NEW HAMPSHIRE

A. ROADSIDE STEEL BEAM

1. BCT
   Have not used.

2. TURNED-DOWN
   a) Last 25 feet twisted 90 degrees with no posts.
   b) Spacing between first two posts of 12 feet, 6 inches with remainder spaced at 6 feet, 3 inches.
   c) Total length of terminal section is 75 feet.
   d) Flare is a 16-degree curve with the end offset 8 feet over the distance of 75 feet.
   e) The end anchor and part of the last 25-foot section is buried.

3. OTHER
   a) Terminal Post at Departure End
      Guardrail has a curved end shoe and the end post is buried a depth of 3 feet, 2 1/2 inches. The post adjacent to the end post is anchored underground.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

1. CABLE
   A 42-foot terminal section is provided with a 4-foot flare. The cables are twisted 90 degrees over the last 18 feet and anchored.

C. MEDIAN-BARRIER END TREATMENTS

   Information not available.

D. GUIDELINES

   Normally use a W-beam guardrail and a turned-down (twist) terminal unit for approaching traffic.
A. ROADSIDE STEEL BEAM

1. BCT
   a) End section is flared and offset 4 feet or more where possible.
   b) Where flared offset is less than 4 feet, a 25-foot flared rail element is required at the beginning of the installation.
   c) Posts are spaced at 6 feet, 3 inches where obstruction or hazard is at least 4 feet from guardrail placement. In all cases, the last five posts are spaced at 6 feet, 3 inches.
   d) The terminal posts are 6 by 8 inches and are wood. Approach posts are steel.
   e) Terminal posts are anchored in concrete.
   f) A diaphragm is used in the nose cone.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Buried-in-Cut-Slope
      Where possible, the approach end of the guardrail is buried in the cut slope. However, no specifications were provided in survey response.
   b) Downstream End-Treatment
      End is cable anchored in concrete footing. Footing has a minimum diameter of 1 foot, 6 inches and is 5 feet long, placed flush with the ground. Cable goes through last post and ties in with footing 1 foot below ground line.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENT

1. Median BCT has been used where dual face beam guardrail has been terminated in a median. MBCT has 3/16-inch by 30-inch steel plate that extends over a section of 25 feet at the terminal section. End post is 6 by 8 inches with 6- by 6-inch wood blocks attached to post and steel plate. The next four posts are 8- by - inches and 6- by 8-inch wood blocks tie post to steel plate.

2. When clearance from back of rail to obstruction is more than 2 feet but less than 4 feet, two BCT's are used in medians. The two BCT's are spaced so the end of one (nearest oncoming traffic) extends 6 feet, 3 inches beyond the end of the other BCT (farthest from oncoming traffic). The end of the BCT farthest from oncoming traffic is spaced 2 feet from the next to last post of the other BCT. BCT nearest oncoming traffic has flare typical for approach end and BCT farthest from oncoming traffic...
traffic has flare typical for trailing end.

D. GUIDELINES

1. BCT is used at all steel-beam guardrail ends with the following exceptions:
   a) Where the approach end can be buried in a cut slope,
   b) Where the guardrail begins or terminates at a structure, and
   c) Where the trailing end cannot be impacted by a vehicle traveling in the opposite direction.

2. The cable-anchored end treatment is used where the trailing end cannot be impacted by a vehicle traveling in the opposite direction.

3. Median BCT has been used where dual-face beam guardrail has been terminated in a median.

4. Where clearance from back of rail to obstruction is more than 2 feet but less than 4 feet, two BCT's are used in medians.
NEW MEXICO

A. ROADSIDE STEEL BEAM

1. ECT
   a) Both steel- and wood-post installations are used. Spacing of both steel and wood posts are the same as 1977 AASHTO Guide.
   b) For steel-post installation, the two breakaway posts at end are 6 by 6 by 0.1875 inches and are placed in a concrete footing.
   c) For wood-post installation, the two breakaway wood posts at end are 5-1/2 by 7-1/2 inches and are placed in steel tube for anchorage.
   d) For both types, the end section is offset 4 feet over a 37 1/2-foot parabola.

2. TURNED-DOWN
   a) A 25-foot section of rail is used with two posts and anchor. The length of guardrail between anchor and last post is 18 feet, 6-7/8 inches. The rail is twisted 90 degrees over the 25-foot distance.
   b) Concrete anchor block is placed flush with ground line and is 5 feet long by 1.5 feet in diameter.
   c) End section is not offset.

3. OTHER
   Use not indicated in survey response.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENT
   No information provided in survey response.

D. GUIDELINES
   No information provided in survey response.
NEW YORK

A. ROADSIDE STEEL BEAM

1. BCT
   BCT is not used.

2. TURNED-DOWN
   a) Steel Weak Post End Treatment
      Total end-section length is 50 feet. The concrete anchored end is offset 4 feet from mainline guardrail. The last post and next-to-last post are offset 12 inches and 6 inches, respectively. The last 25 feet has no posts and is twisted 90 degrees. Posts are spaced at 12 feet, 6 inches for the remaining distance. The twisted portion of rail intersects ground line approximately midway between last post and anchor. Concrete anchor is approximately 3.5 by 3 feet.
   b) Heavy Post Block-Out Corrugated Beam Guardrail
      Total offset varies from 13.5 feet to 30 feet, 10 inches, depending on length of tangent section. Minimum length of tangent section is to be used when fixed object is at point of need. Posts are spaced at 6 feet, 3 inches.

3. OTHER
   No use indicated in survey response.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

1. BOX-BEAM GUARDRAIL
   a) End section is turned down over 3 feet, 11 inches.
   b) Spacing between last post and anchor post is 4 feet, 7 inches.
   c) Offset is 12.5 feet over last 72 feet.
   d) The flared section is curved on a radius of 205.25 feet.
   e) Steel posts are anchored underground into a steel plate.

2. CABLE GUARDRAIL
   a) End section is 42 feet.
   b) Anchor is offset 4 feet from face of tangent guardrail.
   c) There are no posts in the last 18 feet. The next four posts are spaced at 6 feet. These four posts, beginning nearest the anchor and progressing toward tangent section are offset 1 foot 8 inches, 1 foot, 6 inches, and 2 inches, respectively.
   d) The turned down portion of cable intersects ground level approximately midway between last post and anchor.

C. MEDIAN-BARRIER END TREATMENTS

1. STEEL BEAM
   a) Heavy post blocked-out steel beam median barrier is used.
   b) Double-faced rail is joined together and turned down over a distance of 25 feet.
   c) Minimum length of flare prior to median pier is 150 feet.
d) Post spacing is 6 feet, 3 inches throughout.
e) End section is anchored in concrete.

2. BOX BEAM
a) End section is turned down over a length of 18 feet.
b) Box-beam rails are spaced 6 feet at end section.
c) Last post is 15 feet from concrete anchor.

D. GUIDELINES

No specific guidelines for end treatments included in response.
NORTH CAROLINA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, offset distance and spacing of posts are the same as 1977 AASHTO Guide.
   b) Both steel and wood approach posts are used. Wood terminal posts are used in both cases and are 6 by 8 inches.
   c) For anchoring end posts, either concrete footing or steel-tube footing is used.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Buried-in-Cut-Slope
      Taper of end section is 12.5:1 with a maximum offset of 17 feet.
   b) Downstream End Treatment
      Cable anchor terminal is used. A cable extends from the bottom of the last post to an anchor plate placed on the guardrail 12 inches from the center of the next to the last post. For concrete footing, 6- by 8-inch posts are used. For steel-tube footing, 5- by 7 1/2-inch posts are used.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENTS

1. Two BCT's are used with end treatment nearest oncoming traffic offset from tangent section by 4 feet. BCT farthest from oncoming traffic is offset 2 feet from tangent section.

2. BCT farthest from oncoming traffic is spaced 12.5 feet downstream from BCT nearest oncoming traffic.

D. GUIDELINES

   None given in survey response.
NORTH DAKOTA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Standard end treatment is BCT, which is transitioned into a box-beam guardrail.
   b) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   c) Wood 8- by 8-inch posts are used for the terminal posts.
   d) Terminal posts are anchored in 24-inch concrete footings and are wrapped with sheet metal.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   Use not indicated.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

1. BOX BEAM
   Box-beam guardrail is used with BCT as standard end treatment and a transition from the BCT end treatment to the box-beam guardrail.

2. CABLE
   Three-cable guardrail is used with end treatment consisting of a turnbuckle anchor rod tied into concrete footing.

C. MEDIAN-BARRIER END TREATMENTS

   No information provided in survey response.

D. GUIDELINES

   Standard guardrail is box beam with BCT end treatment with a transition from the BCT end treatment to the box-beam guardrail.
OHIO

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are
      the same as 1977 AASHTO Guide.
   b) Only wood posts are used for approach end terminal. Two end
      posts are 6 by 8 inches.
   c) End posts are encased in concrete footing, which is 24 inches
      in diameter by 3 feet, 5 inches long. End posts also may be
      placed in steel tube, which is 5 feet long.
   d) A diaphragm is used in the end-section nose.

2. TURNED-DOWN
   a) End section is 25 feet long.
   b) A single 25-foot rail element is twisted 90 degrees.
   c) Offset distance is 1.5 feet.
   d) Distance between concrete anchor and first post is 18 feet, 9
      inches. Distance to next post is 6 feet, 3 inches.
   e) Concrete anchor, which is 36 inches in diameter and a minimum
      3 feet, 10 inches deep, is used.
   f) Last two posts are anchored in concrete.

3. OTHER
   Downstream End Treatment
   A brace rod is connected between the last two posts and these
   posts are anchored in concrete footing. This brace is connected
   to the bottom of the end post and to a plate, which is placed
   behind the guardrail at the next to the last post.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENTS

   1. For median width of 25 feet or less, back-to-back rails are
      turned down over a 25-foot section. Spacing of posts are same
      as single turned-down rail.

   2. For median width 26 feet or greater, end treatment is a
      continuous rail with the two sides joined together with a
      12.5-foot section on a 40-foot radius with the nose section of
      12.5 feet on a 5-foot radius.

D. GUIDELINES

   1. Turned-down end is used for highways having less than 1,000 ADT
      or design speed less than 50 mph whenever shoulder width is
      insufficient to provide the standard flares.

   2. BCT end treatment is used on approach end along directional
      roadways and at both the approach and trailing ends along two-
way roads. BCT is used for high-volume highways at the end of a standard flare.

3. BCT also may be specified for drive openings whenever sufficient berm width is available.

4. Guidelines for median end treatments are same as noted in C above.
OKLAHOMA

A. ROADSIDE STEEL BEAM

1. Use of BCT was discontinued because of cost and lack of availability of replacement parts.

2. TURNED-DOWN

   a) Total end section length is 75 feet. The section between concrete footing and next post is 25 feet long and is twisted 90 degrees. The next 25-foot section is curved on a radius of 470 feet.
   
   b) The end anchor is set in a concrete footing and is offset 2 feet. The next two posts are spaced at 12.5 feet and the offset distances are 2.17 and 2.0 feet, respectively.
   
   c) The first post is 25 feet from the end anchor followed by a post at a spacing of 12.5 feet. Both of these posts are 6- by 8-inch posts with no blockout. Thereafter, standard 6- by 8-inch posts with 6- by 8-inch blockouts are placed on 6.25 foot centers.
   
   d) The first eight posts have two-inch holes drilled in the eight-inch side.
   
   e) The guardrail is not bolted to the first eight posts. With the bolts removed, the rail will be depressed to the ground when impacted.

3. OTHER

   No information provided in survey response.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   No information provided in survey response.

C. MEDIAN-BARRIER END TREATMENTS

   Turned-down end treatment is used with each of double-faced rails twisted 90 degrees down to ground over 25 feet. There are no posts in the last 25 feet. Other posts are spaced at 6.25 feet. Concrete anchor is same as regular turned-down treatment.

D. GUIDELINES

   Turned-down end treatment is used exclusively. In replacing and updating old guardrail in place, the 4-foot offset is used where possible.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Use 6- by 8-inch wooden posts placed in concrete footings.
   b) End is offset a minimum of 4 feet with a desirable offset of 10 feet.
   c) Length of total end treatment varies with offset distance. This length increases from 50 feet for a 4-foot offset to 112.5 feet for an 8-foot offset.
   d) Spacing of posts is 6 feet, 3 inches.
   e) End is anchored in concrete.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   Downstream Terminal
   This end treatment involves anchoring the guardrail (between the first and second post) to a buried concrete-block anchor with an anchor rod.

B. OTHER TYPES OF ROADSIDE GUARDRAIL
   Use not indicated.

C. MEDIAN-BARRIER END TREATMENT
   No information supplied.

D. GUIDELINES
   None given.
PENNSYLVANIA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Guardrail is offset on a flare over a length of 37 feet, 6 inches with a maximum offset of 4 feet, 3 1/4 inches.
   b) Post spacing for steel posts is same as in 1977 AASHTO Guide.
   c) Uses only steel breakaway posts anchored in concrete footing.

2. TURNED-DOWN
   a) For weak post (aluminum alloy) design, the last 25 feet are turned 90 degrees with no posts and buried between the last post and concrete anchor. Offset over last 25 feet is 4 feet, 6 inches. Also, there is a 12-inch taper the next 12.5 feet back.
   b) For strong post (steel) design, the last 37.5 feet with posts spaced at 6 feet, 3 inches are turned through 90 degrees and anchored in concrete.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

Three different types of end treatments are used, depending upon the width of the median:
   a) BCT, with a 150-foot parabolic flare (median width 30-foot minimum),
   b) Weak-post turned-down design, with a 75-foot minimum parabolic flare (median width 40-foot minimum), and
   c) Treatment for median widths of 20 to 40 feet, parallel rails are spliced together in last 25 feet by cutting one rail off 13.5 feet from last post and splicing it to the other rail. The rails are turned through 90 degrees over the last 25 feet and anchored in concrete.

D. GUIDELINES

1. Buried-in-cut-slope is preferred over all other treatments, even when rail must be extended a short way to accomplish this.

2. For strong post guardrail systems, when the end cannot be buried in a cut slope, the BCT should be utilized on the approach end and on both ends of the rail for two-lane highways. When the necessary offset and slope for the BCT cannot be obtained, use turned-down end treatment.

3. For weak-post guardrail systems, when the end cannot be buried in a cut slope, use a turned-down end treatment.
RHODE ISLAND

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide (steel-post design).
   b) Steel post design is used. Last two posts are wood -- 6 by 8 inches.
   c) Breakaway end posts are anchored in concrete footing 36 inches in diameter by 36 inches deep. End posts are placed in cardboard sonar tubes or metal sleeves.
   d) Diaphragm is used in nose-cone section.

2. TURNED-DOWN
   a) End section is slanted into ground over a length of 37.5 feet.
   b) Post spacing is 6 feet, 3 inches throughout.
   c) Rub rail also is carried underground and ends at third post from end.

3. OTHER
   a) Buried-in-Cut-Slope
      Flare is over a distance of 31 feet, 3 inches. Offset distance at buried end varies from 9 to 15 feet.
   b) Trailing End
      Treatment is cable-anchored in reinforced concrete footing. Distance from last post to concrete footing is 5.5 feet.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No information provided in survey response.

C. MEDIAN-BARRIER END TREATMENTS

No information specifically provided for medians. However, double-faced end treatment (which could be used in medians) is turned down similar to single-faced turned-down end treatment previously summarized.

D. GUIDELINES

1. Turned-down and buried-in-cut-slope end treatments are used where field conditions permit.
2. The BCT is used where other types of end treatments cannot be used.
3. On narrow undivided highways, the approach end treatment is used on both ends.
SOUTH CAROLINA

A. ROADSIDE STEEL BEAM

1. BCT
   a) End section is offset a minimum of 4 feet over a flare distance of 37.5 feet.
   b) Post spacings are 6 feet, 3 inches.
   c) All posts are 6- by 8-inch wood.
   d) End posts are anchored in concrete footing. Welded wire-fabric cylinder is placed on each side of post within the concrete footing.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Buried-in-Cut-Slope
      End section is flared into cut slope over a distance of 125 feet. The end is flared at the rate of 10:1. End is anchored in cut slope and bolted to a concrete footing.
   b) Downstream End Treatment
      End post is anchored in concrete and cable is attached from top of guardrail to bottom of end post.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No information provided in survey response.

C. MEDIAN-BARRIER END TREATMENTS

For medians less than 60 feet wide, two sections of guardrail are placed back-to-back at a taper of 10:1 or over a flare distance of 112.5 feet, whichever is greater. End is offset 10 feet from tangent. Type of anchor is unknown. Ends of back-to-back are spaced 5 feet apart laterally. A distance of 12.5 feet is between the end of rail nearest oncoming traffic and the end of rail farthest from oncoming traffic.

D. GUIDELINES

None given.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use 5 1/2- by 7 1/2-inch wood breakaway terminal posts placed in steel tubes (rather than concrete) for footings.
   c) Approach posts are also wood.

2. TURNED-DOWN
   Do not use.

3. OTHER
   Trailing End Terminal
   Cable anchored from guardrail to end post as in BCT. Last post is a 5 1/2- by 7 1/2-inch wood post inserted in a steel tube. A standard terminal section (end shoe) is used rather than the "boxing glove" used in BCT.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

No information available.

D. GUIDELINES

Only approach end treatment used in BCT.
TENNESSEE

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use 6- by 8-inch wood breakaway terminal posts placed in either concrete footing or steel tube. When placed in concrete, post may be surrounded by sand with a joint seal material at the top or wrapped with 1/4-inch polystyrene foam.
   c) Approach posts are steel.

2. TURNED-DOWN
   Use not indicated.

3. OTHER
   a) Buried-in-Cut-Slope
      Treatment involves flaring the guardrail over the ditch while maintaining a constant height and attaching the rail to a buried concrete anchor.
   b) Rock Cut
      The guardrail is either attached to a concrete anchor modified to suit the slope or attached directly to the rock face.
   c) Downstream Terminal
      The guardrail is anchored by a cable attached to the guardrail between the first and second post and to a buried concrete anchor placed 5 feet, 6 inches behind the last post. Cable is parallel to guardrail for straight runs but may have angle point at anchor plate when guardrail is curved. End of guardrail has a flared end shoe.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

No use indicated.

C. MEDIAN-BARRIER END TREATMENT

BCT-type treatment in direction of traffic installed parallel to median centerline when median is 30 feet or less in width and installed with typical BCT flare when median width is greater than 30 feet. Parallel guardrail for end on downstream end stops at third post with a rounded end section element. First four posts are breakaway.

D. GUIDELINES

Upgrading of guardrail is performed on various projects as they are let to contract for resurfacing, widening, or safety upgrading of a roadway. An effort is made to provide additional embankments for flare needed for BCT. In situations when older section of guardrail is damaged, it is generally replaced in-kind without upgrading to current standards.
TEXAS

A. ROADSIDE STEEL BEAM

1. BCT
   Not used.

2. TURNED-DOWN
   a) A 25-foot long rail section is twisted 90 degrees and secured to a buried concrete anchor.
   b) No posts are used within this 25-foot section.
   c) The first two post spacings are 12 feet, 6 inches followed by 6-feet, 3-inch spacings.
   d) The end is not offset.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

   No information available.

D. GUIDELINES

   BCT is not used. The turned-down end is used whenever guardrail is installed without regard to highway class, traffic volume or speed, or geometrics.
A. ROADSIDE STEEL BEAM

1. BCT
   Use not indicated.

2. TURNED-DOWN
   a) The approach element is 25 feet plus end section.
   b) The last 25 feet are twisted 90 degrees with posts spaced at 6 feet, 3 inches.
   c) The end is not offset.

3. OTHER
   No other information provided.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

BOX BEAM
An 18-foot section is flared to the ground and anchored. The last post is approximately 9 feet from the end. The anchored end is not offset.

C. MEDIAN-BARRIER END TREATMENT

The turned-down end treatment is used.

D. GUIDELINES

The turned-down treatment is installed on the approach guardrail and on trailing end of guardrail in medians and on all guardrail on two-lane roads.
VERMONT

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use both steel and wood (6- by 8-inch) approach and terminal posts.
   c) Use concrete footing for steel posts and either concrete footing or steel tube for wood posts. Place a double wrap of asphalt-treated felt around posts before concrete placement to facilitate replacement of damaged posts.

2. TURNED-DOWN
   a) Last 25 feet are twisted 90 degrees and anchored using a concrete anchor. There are no posts in this 25 feet. About one half of this distance is buried.
   b) End offset is 4 feet.
   c) Total length of treatment is 37.5 feet.

3. OTHER
   Flared Nonbreakaway
   One 12-foot, 6-inch beam section shop-formed to a 16-foot radius is attached to regular guardrail. One intermediate post is placed at 6 foot, 3 inch spacing. Last post is offset 4 feet, 10 inches from normal line of guardrail with a curved end shoe placed on the end.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

No information available.

D. GUIDELINES

Three guardrail end treatments are used in conjunction with W-beam guardrail: the BCT, turned-down, and a flared-nonbreakaway design. Design speed is normally the only consideration used in the selection of the end treatment. On projects having a design speed greater than 40 mph, the BCT is normally specified on approach ends. For projects designed for 40 mph or less, the less expensive "flared-nonbreakaway" end treatment is used. On one-way roadways, such as the interstate where two-way traffic might occasionally be required during maintenance or emergency conditions, the turned-down treatment would usually be specified on the exit end of the guardrail.
VIRGINIA

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide.
   b) Use either steel or wood (6- by 8-inch) approach and terminal posts. For wood posts, use concrete footing. For steel posts, use either concrete footing or stabilizer plate.

2. TURNED-DOWN
   a) A turned-down end terminal is used in conjunction with the weak-post guardrail system. The last 25 feet are turned through 90 degrees with no posts.
   b) The end is offset 4 feet from the face of guardrail line and buried and attached to a concrete anchor. Approximately one-half of the 25-foot section is buried.
   c) Total end treatment is 50 feet with two post spacings at 12 feet, 6 inches before beginning of twist.

3. OTHER
   a) Buried-in-Cut-Slope
      This treatment involves flaring the guardrail across the ditch line and burying the guardrail end into the slope. The end should be a minimum of 1 foot underground. The terminal treatment (from bottom of ditch to end) must be a minimum of 12.5 feet (at least two 6.25-foot spans). The bottom height of guardrail shall be maintained parallel to ditch slope. Flare is not to exceed 15 degrees. A trench no greater than 10 inches in width is to be excavated into the cut slope to provide for the guardrail posts and beam.

   b) Rock Cut
      The rail is flared as with the cut slope. The guardrail is bolted to the rock cut with the guardrail to terminate a minimum of 6 inches below ground elevation of the back slope.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

CABLE
The total end treatment is 42 feet in length. This length consists of four post spacings of 6 feet and then a final spacing of 18 feet between the last post and the anchored end. The cables are twisted and anchored in this 10-foot section. The end anchorage is offset 4 feet in a fill and 5 feet in a cut.

C. MEDIAN-BARRIER END TREATMENT

a) Terminal treatment for blocked-out W-Beam median barrier. Consists of turning down the two parallel guardrails and anchoring each rail over a distance of 37.5 feet with a constant post spacing of 6 feet, 3 inches.

b) Standard W-Beam median barrier (weak-post system)
Consists of turning down the two parallel guardrails over a distance of 27 feet, 1 inch with no posts in this length. One guardrail ends and is spliced to the other at the approximate midpoint of this distance so only one guardrail is anchored.

c) BCT end treatments are used for median-barrier purposes. Either one or two is used, depending upon the geometrics of the location.

D. GUIDELINES

Three types of guardrail are used: a strong post system, a weak-post system, and a cable guardrail. For the strong-post system, the preferred treatment is to bury the end of the guardrail in a cut slope even when the guardrail must be extended a short distance to accomplish this. When the "buried-in-cut-slope" treatment is not practical, the BCT is used. A 4-foot flare is considered essential when using the BCT. A turned-down end treatment is used in conjunction with the weak-post system. When using cable guardrail in close vicinity to a cut section, is should be extended and terminated in the back slope of the cut ditch.
WASHINGTON

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of flared end section is 37.5 feet.
   b) Spacing of posts is 6 feet, 3 inches.
   c) Terminal posts are wood, 6 by 8 inches or 8 by 8 inches.
   d) Another BCT design shows a 100-foot flare with end made up of a 50-foot parabola.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   Buried-in-Cut-Slope
   This end treatment is used with steel end post anchored in concrete. Total length of flare is 5 times tangent offset at maximum flare or a minimum of 100 feet. Height of guardrail carried across ditch is 2 feet, 3 inches from ground level to top of rail.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

   No information provided in survey response.

D. GUIDELINES

1. For new construction or reconstruction, the preferred end treatment is to bury the end in a cut slope.

2. A guardrail barrier may be extended up to 200 feet in order to bury end in a slope.

3. BCT is used when end cannot be buried in cut slope.
WEST VIRGINIA

A. ROADSIDE STEEL BEAM

1. BCT
   a) End section is offset 4 feet over a flare distance of 37.5 feet. A single W-beam continuous section 25 feet long is used at end.
   b) Post spacing is 6 feet, 3 inches throughout.
   c) Approach and terminal posts are wood.
   d) Two end posts are 6- by 8-inch wood posts without offset blocks when concrete-footer end foundation is used. When using tubular-steel end foundation, 5 1/2- by 7 1/2-inch wood posts are used without offset blocks.

2. TURNED-DOWN
   Use not indicated in survey response.

3. OTHER
   a) Buried-in-Cut-Slope
      1) Cut-Slope Terminal (CST), Type A is for anchoring into soft shale or soil. For this case, the guardrail extends a minimum of two 6-foot, 3-inch spans into the cut slope. End is terminated a minimum of 1-foot below ground level of the back slope, except in heavy rock outcropping, where the minimum depth may be 6 inches.
      2) Maximum longitudinal distance is 200 feet. If slope is not encountered in 200 feet, a BCT is used.
      3) Flare length is based on lateral distance to cut slope.

   b) Rock Cut
      Cut Slope Terminal, Type B is for anchoring into shale or rock cut. The guardrail is flared to the rock cut across the ditch line while maintaining normal rail height. An end shoe is attached to the guardrail and bolted to the rock cut.

   c) Downstream End Treatment
      BCT trailing end is used for all multilane divided highways. Cable is tied into last post and the post is anchored by inserting into steel tube.

   d) Unanchored End Treatments
      Used in some situations, dependent upon AADT and design speed. Length of flare is dependent upon offset, which may vary from 4 feet to 8 feet. Buffer is attached at end of rail.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

Use not indicated in survey response.

C. MEDIAN-BARRIER END TREATMENTS

For 40- and 60-foot medians, a BCT is used for approach end. The BCT ends at center of median area. At a distance of 12.5 feet downstream from end of BCT, another rail is attached to back side of
rail for a distance of 50 feet for 40-foot medians and 62.5 feet for 60-foot medians.

D. GUIDELINES

1. On federal-aid projects, the end terminals are BCT or Cut-Slope Terminal (CST), as applicable.

2. On state projects, end treatments are based on the following table:

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WISCONSIN

A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts and offset distance are the same as 1977 AASHTO Guide.
   b) Standard 4-foot offset is used with a 2-foot minimum offset where space is very limited.
   c) Use 5 1/2- by 7 1/2-inch wood posts anchored in steel tubes.

2. TURNED-DOWN
   a) Last 39 feet, 4 3/4 inches turned through 90 degrees to a concrete anchor with no posts the last 14 feet, 4 3/4 inches.
   b) A 6-foot minimum offset over a 64-foot, 4 3/4-inch minimum flare length.

3. OTHER
   Downstream Terminal
   A cable terminal is used for the downstream end of guardrail installed on divided highways. The cable is connected from the guardrail (between the last two posts) to the last post. The cable attachment to the last post is the same as used for the first post in the BCT treatment. The last post is a 5 1/2- by 7 1/2-inch wood post inserted in a steel tube.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

   Use not indicated.

C. MEDIAN-BARRIER END TREATMENT

   Turned-down end treatments used.

D. GUIDELINES

   Require guardrail ends to be ramped down and flared out to a concrete anchor. The BCT is warranted only for the ends of guardrail that is terminated at or interrupted for driveways or minor side roads. A cable terminal is specified for the downstream ends of guardrail installed on divided highways.
A. ROADSIDE STEEL BEAM

1. BCT
   a) Length of parabola, spacing of posts, and offset distance are the same as 1977 AASHTO Guide when parabolic flare is used.
   b) The parabolic flare is used only when no flare on a 10:1 is possible and is an absolute minimum to turn the BCT away from approach traffic.
   c) Two steel diaphragms (14-gage steel) used in terminal section.
   d) Wood breakaway posts placed in concrete footing used.
   e) The alternate of a sleeve base for the BCT is being added.

2. TURNED-DOWN
   Two treatments are used.
   a) The first (original) involves turning the rail through 90 degrees and anchoring the end over a distance of 25 feet with a constant post spacing of 6 feet, 3 inches.
   b) A modified turned-down treatment is specified in which the rail is again turned through 90 degrees over a length of rail of 25 feet, but no posts are placed in this length. Also, the first five posts have modified post connections in which the rail element is not connected to the posts. Back-up plates are bolted to the wood posts. The rail elements are rested on the back-up plates and held in place with a fastening strap at each post. The end in both instances is at the end of a 10:1 flare so that it is offset 30 feet from the edge of traveled way.

3. OTHER
   a) Downstream Terminal
      A cable and rod is connected from the guardrail (between the first and second posts) to a buried concrete anchor, which is located about 5 feet, 6 inches from the last post.
   b) Buried-in-Cut-Slope
      The rail is flared across the ditch (maintaining guardrail height) and the end is bolted onto a buried concrete anchor block. The guardrail end is offset 7.29 feet from the ditch bottom. A 25-foot section of rail is flared at a radius of 47.75 feet.

B. OTHER TYPES OF ROADSIDE GUARDRAIL

BOX BEAM
An 18-foot section of rail is angled to the ground and anchored in a buried concrete anchor. The last post is about 15 feet from the end. The end is not offset.

C. MEDIAN-BARRIER END TREATMENT

Either the BCT, turned-down, or buried-in-cut slope treatment is used. The rail is flared at a 10:1 slope so the end is 30 feet from
Wyoming (Continued)

the edge of the traveled way whenever possible.

D. GUIDELINES

Normally attempt to locate the end anchorage at least 30 feet from the edge of traveled way for all types of barrier systems. With W-beam and BCT, a minimum 4-foot offset in conjunction with a parabolic flare may be used, but this normally is used only on lower-volume roadways. For W-beam guardrail, three types of approach guardrail end treatments are used: the turned-down (original and modified), the BCT, and the "buried-in-cut-slope" treatment. The "buried-in-cut-slope" is regarded as the safest anchorage and is used whenever the rail can be flared and buried in a cut slope. The BCT is acceptable on any new construction or upgrading project. The original turned-down end treatment is not used on new construction and should be upgraded to the modified version or replaced with a BCT or buried treatment on upgrading projects. The modified turned-down end treatment could be used on new construction but its use is not recommended. On upgrading projects, the modified turned-down treatment should be used where original turned-down treatments are existing and upgrading is to be performed with a minimum cost. In either case, it is not to be located any closer than 200 feet of a bridge end or other hazard that may be impacted by ramping.