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ROADWAY DESIGN DIVISION
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INSTRUCTIONAL BULLETIN NO. 14-02

Regarding Roadside Safety Hardware Design Guidance

PURPOSE: This Instructional Bulletin adds new guidance and revises current existing guidance concerning roadside safety hardware.

Effective for the May 2014 Letting (March 12th Turn-in), Section 4-705.00 through 4-706.39 are revised as attached.

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Roadway Design Division

2/10/14
CS:AH:MC
Attachment

4-705.00 ROADSIDE BARRIERS GENERAL

Roadside barriers are used to protect the traveling public from an unavoidable and unmovable object, body of water, non-traversable slopes, and to prevent lane departures into oncoming traffic. The following sections give guidance on:

- 4-705.10 Warrants: Justify the use of barriers
- 4-705.11 Warrant 1: At Bridges or Box Culverts
- 4-705.12 Warrant 2: Non-Traversable Slopes
- 4-705.13 Warrant 3: Roadside Obstacles
- 4-705.14 Warrant 4: Freeway Median Departures
- 4-705.15 Warrant Exceptions
- 4-705.20 Length of Need: Determine the amount of barrier needed.
- 4-705.30 Barrier Type Selection: Choose the appropriate barrier system.
- 4-705.40 Guardrails
- 4-705.41 Guardrail Special Designs
- 4-705.50 Concrete Median Barriers
- 4-705.60 Cable Barriers

4-705.10 BARRIER WARRANTS

Roadside barriers should only be placed in areas where a roadside hazard exists that cannot be removed and the potential harm from an impact with the barrier is less serious than impacting an object or the potential of overturning resulting from a non-traversable steep slope. The warrants below are meant as a guideline for the designer to make the determination but the guidelines should not be utilized as a substitute to good engineering judgment.

When barriers are indicated by warrant the designer should consider the following before adding barriers:

- Remove the obstacle (Is the obstacle necessary? If not remove the obstacle)
- Relocate the obstacle (If the obstacle is necessary, can it be moved outside of the clear zone?)
- Redesign the obstacle to be safely traversed (Such as flattening a steep 2:1 slope to flatter than 3:1)
- Make obstacle crashworthy, such as breakaway (Typically applies to signs and some poles)

Only if the case when none of the above four conditions can be utilized should the designer use barriers.

4-705.11 WARRANT 1: AT BRIDGES OR CULVERTS

Barriers are warranted anytime the road crosses a bridge, box culvert or slab bridge. Most structures will be designed with a specified concrete bridge rail by the Structures Division. A minimum length of guardrail transition section with proper end terminal must be provided at bridge ends.

For installation details when Warrant 1 is met, see Safety Plan Standard Drawings:

- **S-PL-3** for typical installation at bridge ends
- **S-PL-5** for typical installation at bridge ends in depressed medians

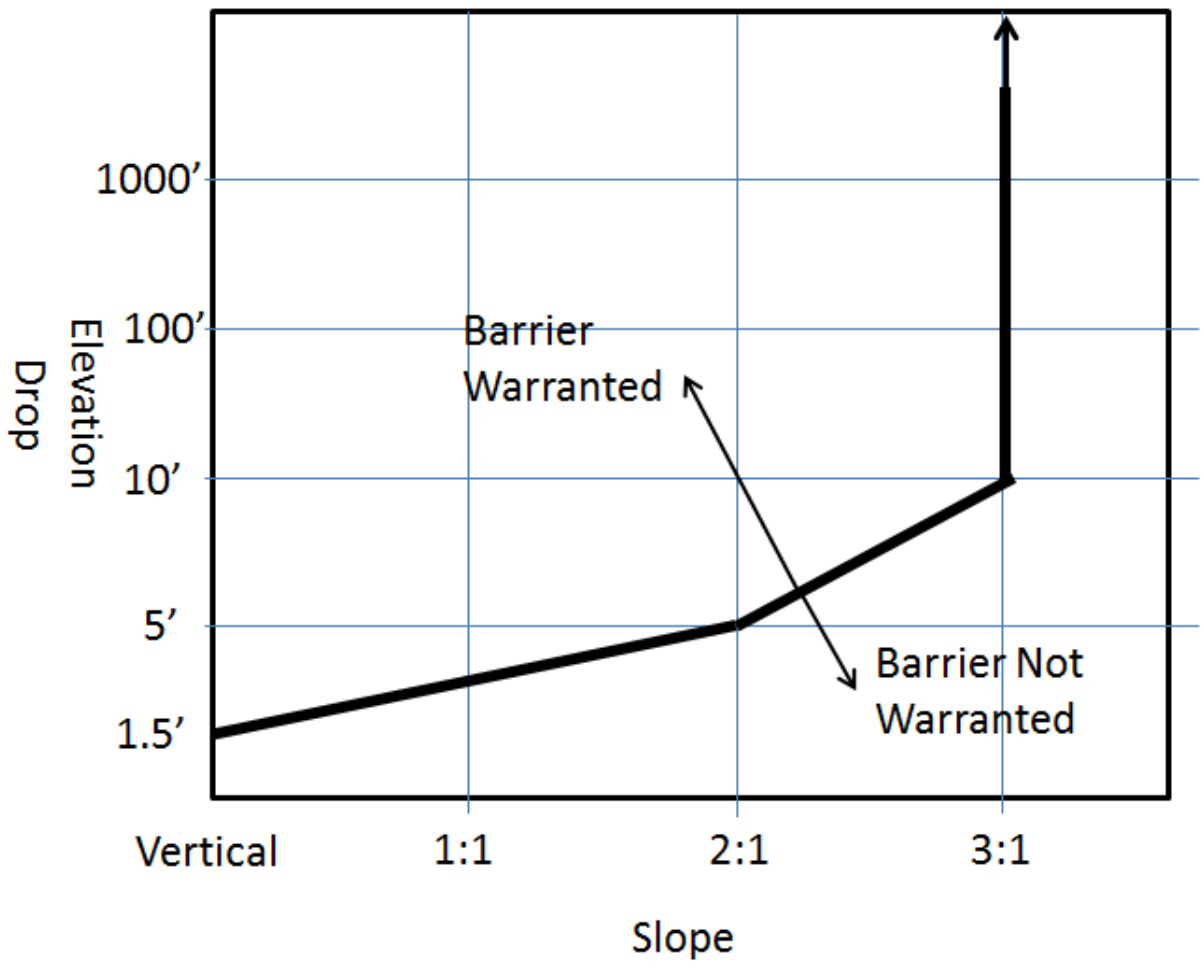
In some cases box culverts or slab bridges may use guardrail instead of concrete bridge rail. The amount of fill over the bridge will determine how the guardrail will be installed. See **Section 4-705.41** and **S-GRS-2** for more information.

4-705.12 WARRANT 2: NON-TRAVERSABLE SLOPES

Barriers are warranted if the combination of nonrecoverable slope (defined by steepness)and the height of the drop off combine to create a hazard of overturning for a vehicle departing the roadway. See the below figure for warrant criteria.

For installation details of barriers when Warrant 2 is met, see Safety Plan Standard Drawings:

- **S-PL-1** for typical installation at hazards
- **S-PL-2** for special installation around driveways or side roads



4-705.13 WARRANT 3: ROADSIDE OBSTACLES

Barriers are warranted anytime an obstacle is found inside the clear zone area (as defined on Standard Drawing **S-CZ-1**) or a hazard is found at the toe of a non-recoverable (3:1 to 4:1) fill slope, even if the clear zone distance is less than the slope length.

For installation details of barriers when Warrant 3 is met, see Safety Plan Standard Drawings:

- **S-PL-1** for typical installation at hazards
- **S-PL-2** for special installation around driveways or side roads

Typical obstacles are listed below, though other obstacles not on the list may also warrant a barrier if determined by engineering judgment.

Typical Roadside Obstacles Warranting Barriers

- Trees
- Poles
- Bridge Abutments
- Bridge Piers (See Standard Drawing **S-PL-4** for special requirements for bridge piers)
- Streams
- Traffic Signal Supports
- Large Sign Supports

In general the following roadside objects are not considered hazards. These objects may be installed in the clear zone (as long as noted conditions are met) without the need for shielding.

Typical Objects Not Warranting Barriers

- Objects utilizing breakaway supports approved by the Department such as signs posts
- Relatively smooth vertical backslopes (such as rock cuts) generally do not require protection as impacting a barrier is unlikely to provide any benefit to the occupant of the vehicle as opposed to striking the vertical backslope. Delineation of the backslope is recommended on the outside of a curve.
- Right-of-Way Fences
- Cross drains utilizing standard D-PE endwalls or side drains with D-SEW endwalls. These endwalls are designed to be traversable and will allow a vehicle to safely pass over.
- Small trees (less than 4” in diameter)

4-705.14 WARRANT 4: FREEWAY MEDIAN DEPARTURES

On full or semi-full access controlled highways (freeways) opposing lanes of traffic are separated by a median or (if no median) a concrete median barrier (in rare cases median divider guardrail may be substituted). In cases when the freeway is separated by a median, the width of the median and average daily traffic volume (ADT) may create a situation when median crossover crashes have a high probability of occurring. If one or more of the below conditions exist barriers are warranted for the median.

This warrant is independent of and superseded by warrants 1 through 3. In cases where a bridge end, obstacle, or steep slope is present in the median; placing barriers for those conditions take precedence.

For installation of barriers when Warrant 4 is met, see Safety Plan Standard Drawing: **S-PL-6**

Conditions Warranting Barriers in Median

- Freeways not separated by a median require concrete median barrier (See **RD01-TS-5B)**
- Freeways with medians 30 feet or narrower
- Freeways with medians between 30 and 50 feet with ADT > 20,000 vehicles/day
- Freeways with medians not meeting any above condition but with significant crash history

4-705.15 EXCEPTIONS TO BARRIER WARRANTS

In certain cases barriers should not be placed because doing so would: be undesirable for the level of access provided by the roadway, be infeasible due to lack of sufficient space, or cause greater safety hazards than the hazard being shielded. In general the following conditions generally do not warrant barrier protection.

Urban Streets: Barriers are typically not recommended on low speed (30 MPH and less) urban roadways because:

- Low speeds make roadway departure crashes less likely and less severe
- Urban areas require higher access that would be hindered by barriers
- Urban areas have many more intersections that make barrier installation impractical

Small Sections with Short Drop-offs: Barriers are typically not recommended to protect small sections of roadway (Less than 100 feet along centerline) with drop-offs less than 10 feet because the risk from a vehicle encroaching this section is less than the risk of striking a barrier system.

Utility Poles: In many cases utility poles share TDOT right-of-way and often times are in the clear zone of rural highways. It is undesirable, impractical and infeasible to install barriers to protect every utility pole. Every effort should be made to coordinate with the utility company to install the poles as far away from the edge of the roadway to mitigate risk. For poles that cannot be moved away from the clear zone the poles should be delineated.

4-705.20 BARRIER LENGTH OF NEED

Once the need for a barrier is determined the next step is to calculate the amount of barrier needed. The distance required is referred to as "Length of Need" (LON). The Safety Plan Standard Drawing series drawings show typical installations for various cases.

- S-PL-1: LON along the roadway for objects or hazards (Warrants 2 and 3)
- S-PL-2: Typical installation if a side road/driveway is located within the LON required for another hazard. (Warrants 1-3)
- S-PL-3: Minimum LON to protect bridge ends (Warrant 1)
- S-PL-4: Barrier requirements and LON to shield structures in the clear zone. (Warrant 2)
- S-PL-5: Minimum LON to protect bridge ends in the median (Warrant 1)

4-705.30 BARRIER TYPE SELECTION CRITERIA

Utilize the following guidelines to determine the appropriate system. See appropriate standard drawing for details of each system

A) BARRIER TYPE SELECTION CRITERIA FOR WARRANTS 1 THROUGH 3 (4-705.11 THRU 4-705.13)

(Typical hazards: bridge piers, abutments, retaining walls, sign supports, etc)

a. If the distance from the edge of shoulder to the object is less than 4 feet: Use concrete median barrier (half wall) or wall specified by Structures Division.
b. If the distance from the edge of shoulder to the object is greater than 4 feet: Use guardrail

B) BARRIER TYPE SELECTION CRITERIA FOR WARRANT 4 (4-705.14)

(Median crossover crashes)

a. Medians wider than 32' use cable barrier.
b. Medians narrower than 32' use concrete barrier or median divider guardrail. Concrete median barrier is preferred but for short section median divider guardrail is acceptable.

4-705.40 GUARDRAILS

Guardrails consist of a Steel W-Beam supported by wooden or steel posts. For guardrail sections to be effective an anchor (typically installed in conjunction with an end terminal) must be installed at each end. At impact guardrail deflects up to 3 feet, therefore to provide the system with room to function four feet behind the guardrail should be kept clear of obstructions. Ends of guardrails must be terminated with an approved crashworthy end terminal (See Section 4-706.20). See **S-GR31-1** for more details

Double sided guardrail (Median Divider Guardrail) may be used in limited cases in the median in place of concrete barriers, particularly when the required length is relatively short. Median divider guardrails are also used when a guardrail may be subject to impacts from either side. In cases where the median divider guardrail is installed near the edge of pavement is important that the area between the posts is free of asphalt. See **S-GR31-2** for more details.

4-405.41 GUARDRAIL SPECIAL DESIGNS

Due to site conditions sometimes a guardrail system may not be installed as shown on standard drawing S-GR31-1. However, there are several approved special installations that may be utilized.

Guardrail at Underground Conflicts: In the case when a utility or pipe culvert prevents driving guardrail posts the designer shall refer to:

- **S-GRS-1** if only one post is affected by the obstruction and
- **S-GRS-3** if multiple posts are affected.

Guardrail across Box Culvert or Slab Bridge: In the case when guardrail is run across a box culvert or slab bridge that has fill of less than 3' 4" over the deck the designer shall refer to **S-GRS-2**. In this case the guardrail will be paid for under item 705-01.04. If the fill is greater than 3' 4" guardrail will be installed in the typical method as shown on **S-GR31-1**.

Guardrail at Intersections: When the length of need for guardrail extends beyond the location of an intersection or a drive way, the guardrail shall be curved around the intersection radius and type in-line anchors installed as shown on **S-PL-2**.

Guardrail at Steep Slopes: When a guardrail has to be installed where the 2' earth pad behind the post cannot be installed on a slope steeper than 6:1 the length of the posts shall be increased to 8 feet. See Detail E on **S-PL-6** and General Note L on **S-GR31-1.**

4-705.50 CONCRETE MEDIAN BARRIERS

Concrete Barrier is a rigid barrier consisting of a 32" or 51" (The additional 19" included on the 51" wall is primarily used as a glare screen to limit headlight glare from opposing lanes in urban areas) tall reinforced concrete wall. TDOT utilizes a single slope wall. At impact the barrier wall does not deflect, resulting in a near sudden deceleration for the occupant of the impacting vehicle. Because of the severity of impacts with a concrete barrier the system should only be used when the level of protection is required. Therefore they are best suited for:

- To prevent crossover crashes at narrow medians.
- To prevent catastrophic damage to structures near the roadway.
- To protect larger vehicles from falling off of a steep (vertical or nearly so) drop off.

See **S-SSMB-Series** drawings for more details on Concrete Median Barriers.

The ends of concrete median barrier walls are considered a roadside hazard because of their unyielding nature. Because of this, the ends must be protected by means of an approved crash cushion (attenuator) or connected to guardrail system with end terminal. When guardrail is used to protect the end of concrete barrier wall a semi-rigid guardrail transition must be used to prevent the guardrail from deflecting such to create a pocket that would allow a vehicle to impact the end of the wall. See the guardrail connection standard drawings (**S-GRC-series**) for details of the semi-rigid transition guardrail.

4-705.60 CABLE BARRIERS

Cable barrier consists of three or four high tension steel cables supported by steel posts. Cable barriers like guardrails require an anchor to provide the tension for the system to operate. Cable barriers are designed to perform for impacts on either side, thus only one run is necessary to protect a median against crossovers. However, at impact cable barriers deflect up to 9 feet. Because of the large deflection cable barriers are not suited to shield objects close to the roadway or narrow medians. Cable barrier systems are designed to be used on 6:1 or flatter slopes.

Cable barrier systems end with a cable barrier terminal that consists solely of the anchoring system. Cable Barrier Terminals should not be included in the length of need since they do not provide re-directive protection and should be overlapped by another barrier system if the need for protection exists at that location.

4-706.00 END TREATMENTS

To prevent the end of barrier systems from themselves becoming hazards to the driving public the ends must be protected with either an attenuator or end terminal. The follow sections discus the design considerations for:

- 4-706.10 Anchorages
- 4-706.20 Guardrail End Terminals
- 4-705.30-.39 Crash Cushions

4-706.10 ANCHORAGES

For Guardrails to function properly both ends must be anchored to provide the system with tension. In most cases anchors are installed and paid for in conjunction with an end terminal. Guardrail anchors systems are shown in the **S-GRA-series** drawings.

In cases where the end treatment is facing oncoming traffic an end terminal is required and the anchor is installed with the terminal. (type 12, type 38 or type 21). Note: the anchor for type 38 is proprietary to each qualified end terminal so no standard drawings are provided for them.

When the end of the guardrail is located outside the clear zone of oncoming traffic a crashworthy end treatment may not be required. In this case the anchor is installed and paid for in conjunction with the trailing end terminal. (type 13)

When a guardrail is curved around an intersection or driveway an anchor is installed along the tangent section of guardrail near the point of curvature (See **S-PL-2**). This anchor is to be paid for as an anchor “type in-line.”

Cable Barrier systems also require an anchor at each end. Each system has a proprietary anchor so no standard drawing is provided for cable barrier anchorages. See **S-CB-1** for more information.

4-706.20 GUARDRAIL END TERMINALS

On every road the first choice for approach end terminal shall be the buried in backslope, Guardrail End Terminal (Type 12) (See **S-GRT-1**), Item No. 705-04.02. This system is non-gating (that is the entire system is designed to redirect a vehicle). The buried in backslope end terminal requires a backslope of at least 2:1. Guardrail lengths may be extended up to 200 feet to a section of backslope meeting the backslope requirements. When the above required conditions cannot be achieved, the designer shall use the following guidance to choose the appropriate system:

On any numbered highway (interstate, federal, or state) or local roads with design speeds greater than 40 mph, the tangential energy absorbing guardrail end terminal (type 38) (See **S-GRT-2**) shall be used. For the system to work as designed the earth pad as shown on **S-GRT-2P** must be installed.
Note: The Type 38 is a gating system (that is part of the system does not redirect a vehicle) and the designer shall verify that the gating section (first 12.5 feet) is outside the length of need.

On roads that are not a numbered highway and with low design speeds (40 mph and less) a Slotted Rail Terminal - SRT 75 (Type 21), or equal, may be used instead of a type 38. Payment is to be made under Item No. 705-04.04 Guardrail Terminal (Type 21). See **S-GRT-3.** For the system to work as designed the earth pad as shown on **S-GRT-3P** must be installed.
Note: The Type 21 is a gating system (that is part of the system does not redirect a vehicle) and the designer shall verify that the gating section (first 12.5 feet) is outside the length of need.

4-706.30 DESIGN AND SELECTION CRITERIA FOR CRASH CUSHIONS

4-706.31 GENERAL DESIGN PRINCIPLES

Crash cushions (impact attenuators) are used to shield fixed roadside objects located within the clear zone such as bridge piers, overhead sign supports, ends of retaining walls, concrete median barriers, bridge abutments, and bridge railings. Crash cushions operate on the basis of energy absorption or energy transfer by either decelerating a vehicle to a controlled stop after a frontal impact, or by redirecting a vehicle away from a fixed object after a side impact. Where a fixed roadside object is identified, the designer should first consider removing, relocating, making the object breakaway, or shielding the fixed object with a longitudinal barrier. Where this is impractical, the use of an approved crash cushion system should be considered.

All crash cushions specified on TDOT projects must be accepted as crashworthy by the FHWA in accordance with either NCHRP Report 350 or the AASHTO Manual for Assessing Safety Hardware (MASH) for Test Level 3 (TL-3). This requirement shall apply to all temporary work zone and permanent installations.

4-706.32 WORK ENERGY PRINCIPLE (NON-GATING, RE-DIRECTIVE SYSTEMS)

Crash cushion design based on the work energy principle involves the reduction of an impacting vehicle's kinetic energy to zero. Assuming that a vehicle will be stopped after an impact, then the "work" done on a vehicle equals the initial kinetic energy of the vehicle. An

impact to a crash cushion will result in some damage to a vehicle; however, under the work energy principle, the potential for serious injury to the vehicle occupants is reduced.

Crash cushions that operate under the work energy principle utilize “crushable” or “deformable” material to convert the kinetic energy of a vehicle into other forms of energy including mechanical, potential, heat, and sound energy. Crash cushions of this type, referred to as compression crash cushions require a rigid support back-up structure or foundation to resist the impact force of the vehicle utilizing the energy-absorbing material. These types of crash cushions are considered non-gating, re-directive systems, in that they are not intended to capture the vehicle upon impact (unless frontal impact occurs); but rather, redirect the vehicle after collision. Various systems are available that offer re-directive capabilities on one or both sides of the system.

Table 4-2 summarizes the three types of non-gating/re-directive crash cushion systems considered acceptable for use on TDOT projects. See **Figure 4-19** for selection flowchart.

Non-Gating Crash Cushion Classification	**Roadway Location Characteristics**			
	ADT	**Impact Frequency per Year**	**Distance (D) from Travel Way (feet)**	**Repair Considerations**
Sacrificial	<25,000	N/A[1]	D>10	Requires entire system replacement when hit
Reusable	<25,000	1-2	D>10	Many reusable components, Unlimited repair time
Low Maintenance/Self Restoring	≥25,000	3 or more	D≤10	Time and work space limitations, Multiple hits before repairs needed

[1] Low history or expectation of impacts occurring over lifetime of crash cushion.

Table 4-2
Non-Gating Re-directive Crash Cushion Classification

4-706.33 CONSERVATION OF MOMENTUM PRINCIPLE (GATING SYSTEMS)

The conservation of momentum principle for crash cushion design involves the transfer of the vehicle's momentum to an expandable mass of material located in the vehicle's path. The conservation of momentum principle is involved with all crash cushion impacts, since some portion of a vehicle's kinetic energy is transferred to the cushion by accelerating and moving various components of the cushion during an impact. For gating systems, this expandable mass will normally consist of containers filled with sand. Sometimes referred to as inertial crash cushions, these types of systems require no rigid backup or support to resist a vehicle's impact force, and may be used for both temporary and permanent installations.

Gating systems are energy dissipation devices only, and rely on the conservation of momentum principle. They have no capability to re-direct an errant vehicle; but rather, will either capture a vehicle or allow it to pass through the system along the same general path. Use of a gating crash cushion should be limited to locations where the roadside object is not likely to be impacted at an angle on the side with any significant velocity, or when no other safety device product will fit the location (i.e. very wide hazards). Also, gating systems may be appropriate for use on low speed facilities and in temporary work zones with higher speeds where lane widths are constrained and the potential for a high angle impact is limited. Every gating system must be specifically designed for the fixed object that it is intended to shield.

For gating, non-redirective systems (i.e. sand-filled barrel arrays), the designer should verify that adequate clear run-out area is available behind the device. Barrel arrays should not be used where there is high potential for vehicles to impact the device in the reverse direction (e.g. a vehicle would hit the heaviest barrels placed directly adjacent to the fixed object being shielded).

4-706.34 CRASH CUSHION SELECTION GUIDELINES

The location of all crash cushions should be shown on the Proposed Layout Sheets along with the cushion type for each occurrence of a crash cushion on the project. In addition, the designer should provide the available reserve area (length and width after deducting for offsets - See Figure 4-19A) for each location where a crash cushion is to be installed. The designer will specify the type of crash cushion to be used and the contractor will choose an approved product for that type selected. In some instances, it may be necessary to provide special details for a given location. When special details are required, they should be shown on the Detail Sheets within the final construction plans.

For new construction projects use Figure 4-19 to determine the appropriate type of crash cushion to specify, see Standard Drawing **S-CC-1** for more details. **Maintenance projects** shall follow the maintenance contract.

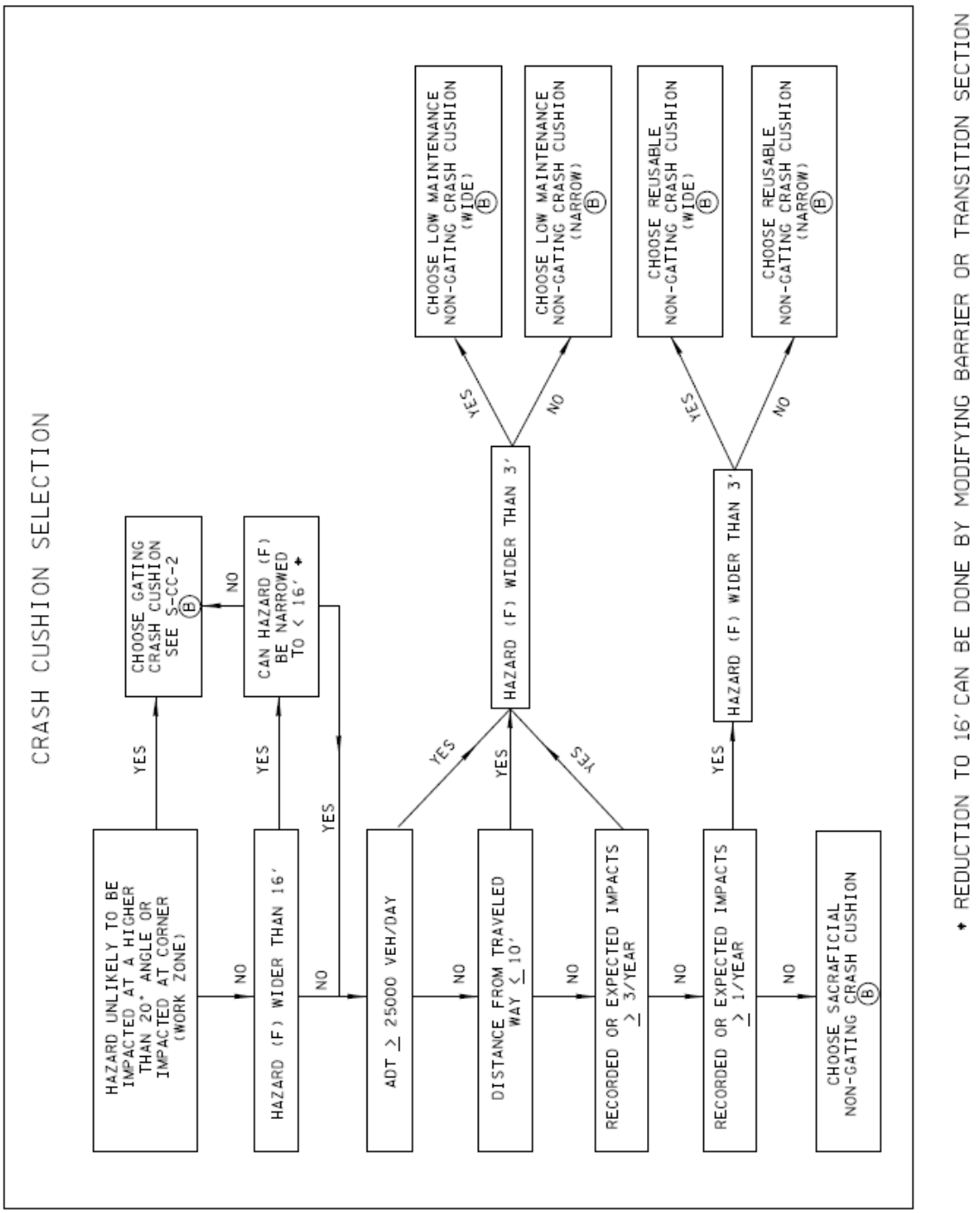


Figure 4-19
Crash Cushion Selection Flowchart

4-706.35 SITE CHARACTERISTICS

Provisions for providing adequate space (reserve area) for crash cushions to shield fixed objects should be made during the preliminary plan stage for new roadway construction projects and for the rehabilitation or reconstruction of existing roadways. Standard Drawing **S-CC-1** provides the minimum and desired reserve area dimensions that should be made available. The preferred condition represents the optimum and desirable values for any location. The unrestricted conditions represent the minimum dimensions for all locations. The restricted conditions shall be used only where it can be demonstrated that dimensions of the unrestricted condition are unattainable. The information in the table is for preliminary design purposes. Final design should be based on the crash cushion system selected and the manufacturer's specifications. Additionally, the table values are generic and may not apply to some proprietary systems.

To allow crash cushions to compress uniformly during an impact, systems should be installed on a hard, smooth, and generally flat surface of asphalt or concrete (preferred). All non-gating systems will require a foundation of this type. This can easily be accommodated for in new construction; however, at retrofit locations or major roadway rehabilitation sites, the designer should attempt to remove sloped surfaces as part of the project plans. Longitudinal and transverse slopes in excess of 5 percent should be avoided. Additionally, if the cross slope varies by more than 2 percent over the length of the system, the designer may need to make site alterations. For gating systems, the hard flat surface should be provided so as to provide a uniform foundation on which the barrel-array pattern may be installed and the design masses of the sand-filled barrels can be marked. These marked locations will aid in the proper reconstruction of the barrel system to its originally designed capacity and configuration after a vehicle impact.

On new construction projects, no curb, curb and gutter, or raised pavement should be designed in the area surrounding or occupied by the crash cushion. When retrofitting an existing location, existing curbs, curb and gutter, or raised pavement should be removed where possible. If an existing curb is to remain, it shall be no more than 4 inches in height. The designer should also verify that the existing curb has not previously contributed to poor crash performance.

The designer should verify if sight distance will be compromised by installing a crash cushion at some intersection locations (i.e. locations at the end of concrete median barriers located at at-grade intersections). Where this is a concern, the designer should choose a system that provides reduced overall height while still meeting the attenuation need at the location.

4-706.36 Voided

4-706.37 Voided

4-706.38 Voided

4-706.39 TEMPORARY WORK ZONES

For temporary work or construction zones, the designer should select a crash cushion system consistent with the expected time and site conditions that may be present at the given location. All crash cushions installed in temporary work zones shall meet Test Level 3 criteria, and each system must be accepted by FHWA as listed on the Qualified Products List. Temporary systems shall be selected, designed, and installed based on the same guidance provided for permanent applications. A generic gating crash cushion design is provided on **S-CC-2.**

Both non-gating and gating systems are approved for use in temporary work zones on TDOT project. Non-gating, redirective systems are available in narrow widths; and thus, have the ability to satisfy attenuation requirements where working conditions are constrained; provided that a paved surface is available for proper anchorage. Where lane widths are constrained, gating systems designed to protect the ends of temporary concrete barrier or other fixed object are acceptable due to the reduced potential for angled impacts. Additionally, some gating systems do not require a paved surface for short-term temporary installation.

With all temporary applications, the selected system should provide adequate separation distance between the installed system and the actual area where work is being performed due to the possibility of flying debris during an impact. Additionally, sight distance at intersecting roadways or points of ingress/egress to the work zone should be considered and checked during the selection process.