contoured to the exterior shape of a concrete median barrier. If the cross slope is flatter than approximately 1V:10H, a barrier could be placed at or near the center of the median (Illustration 6).

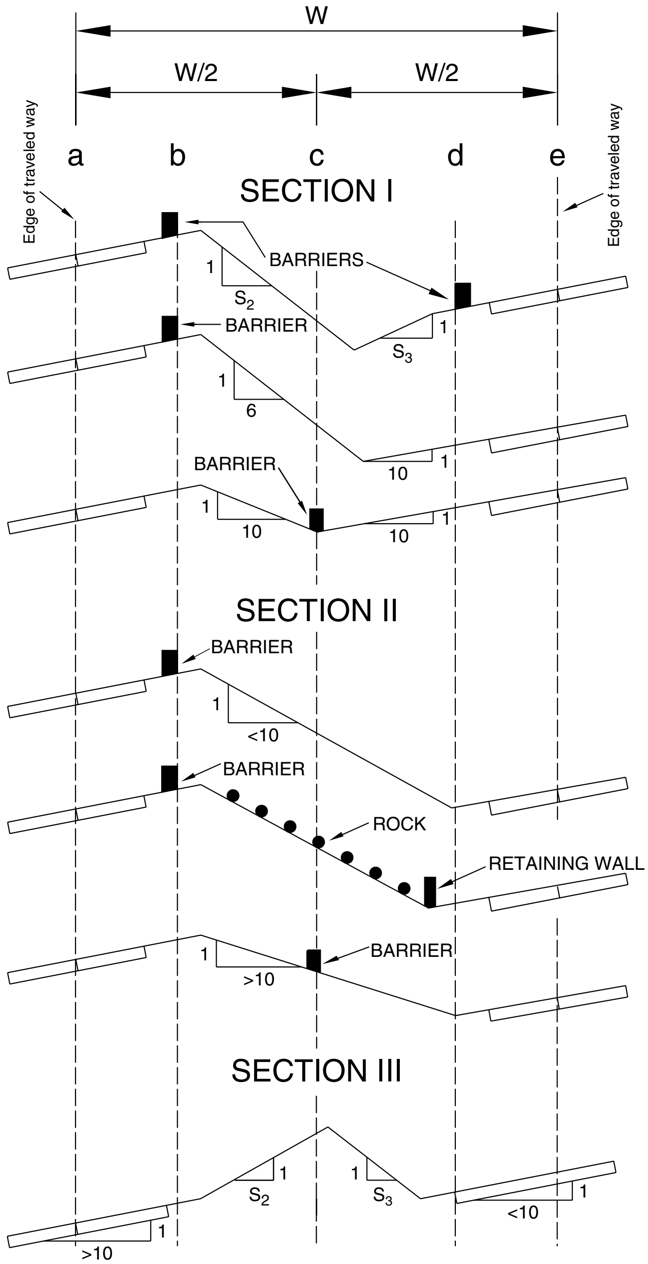

Figure 6-18. Recommended Barrier Placement in Non-Level Medians

6.6.1.3 Median Section III

Placement criteria for median barriers on this cross section (Illustration 7) are not clearly defined. Research has shown that such a cross section, if high enough and wide enough, can redirect vehicles impacting at relatively shallow angles. However, this type of median design generally should not be construed to be a barrier or provide positive protection against crossover crashes.

If slopes are not traversable (e.g., rough rock cut), a roadside barrier should be placed at "b" and "d." If retaining walls are used at "b" and "d," it is recommended that the base of the wall be contoured to the exterior shape of a standard concrete barrier.

When the guidelines suggest installing a median barrier, it is desirable that the same barrier be used throughout the length of need and that it be placed in the middle of relatively flat medians with slopes 1V:6H or flatter. However, it may be necessary to deviate from these guidelines in some cases. For example, the median in Section I, where the roadways are stepped (on significantly different elevations), may call for a barrier on both sides of the median. If a single median barrier is installed upstream and downstream from the section, it may be necessary to split the median barrier, as illustrated in Figure 6-19. Most of the operational median barriers can be split this way, especially box beams, W-beam types, and concrete barrier.

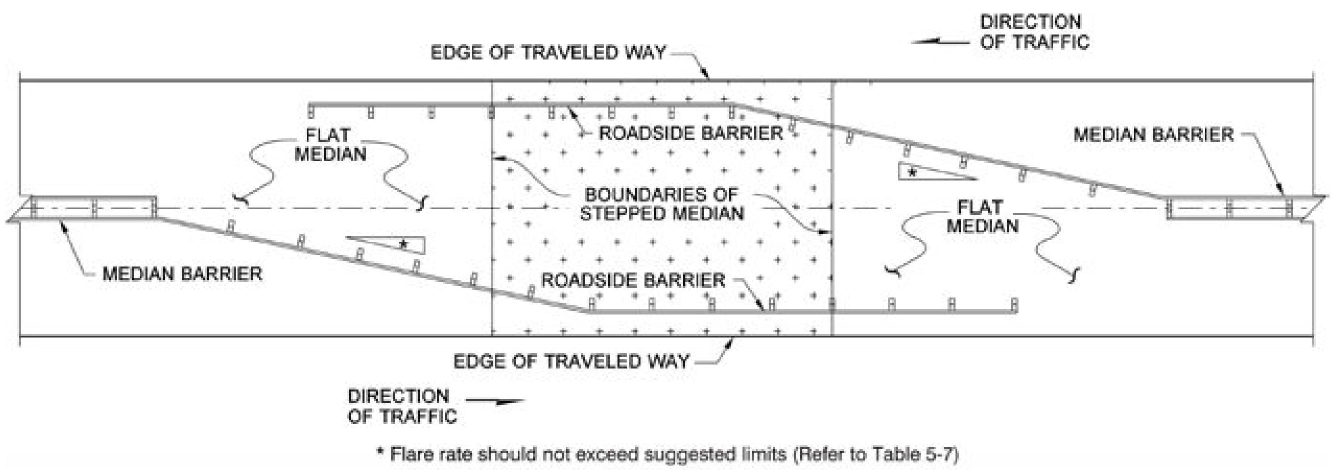

Figure 6-19. Example of a Split Median Barrier Layout

6.6.2 Fixed Objects within the Median

In many locations, an obstacle such as a rigid object may be located in a median. If a median barrier is not being installed and the object is outside of the clear zone for one direction of traffic, the barrier should be treated as a roadside barrier (see Chapter 5). Appropriate flare rates should be used for the approaching traffic side of the barrier and, if the deflection distance for the barrier cannot be provided, a transition may be necessary to stiffen the barrier in advance of the object. In addition, when the object is within the clear zone for both directions, the object and back side of the barrier need to be shielded as well.

Typical examples of objects that often are located in a median are bridge piers and overhead sign support structures. If shielding for both directions of travel is necessary and if the median is flat (i.e., side slopes less than approximately 1V:10H), two means of protection are suggested. In the first case, the designer should investigate the possible use of a crash cushion to shield the object. The second suggestion is to employ either semi-rigid or rigid barriers with crash cushions or end treatments to shield the barrier ends as illustrated in Figure 6-20. If semi-rigid systems are used, the distance from the barrier to the obstruction should be greater than the dynamic deflection of the barrier. If a concrete barrier is used, the barrier can be placed adjacent to the obstruction unless there is a concern that a high-center-of-gravity vehicle will strike the obstruction because its contact with the barrier causes the top of the vehicle to lean over the railing.

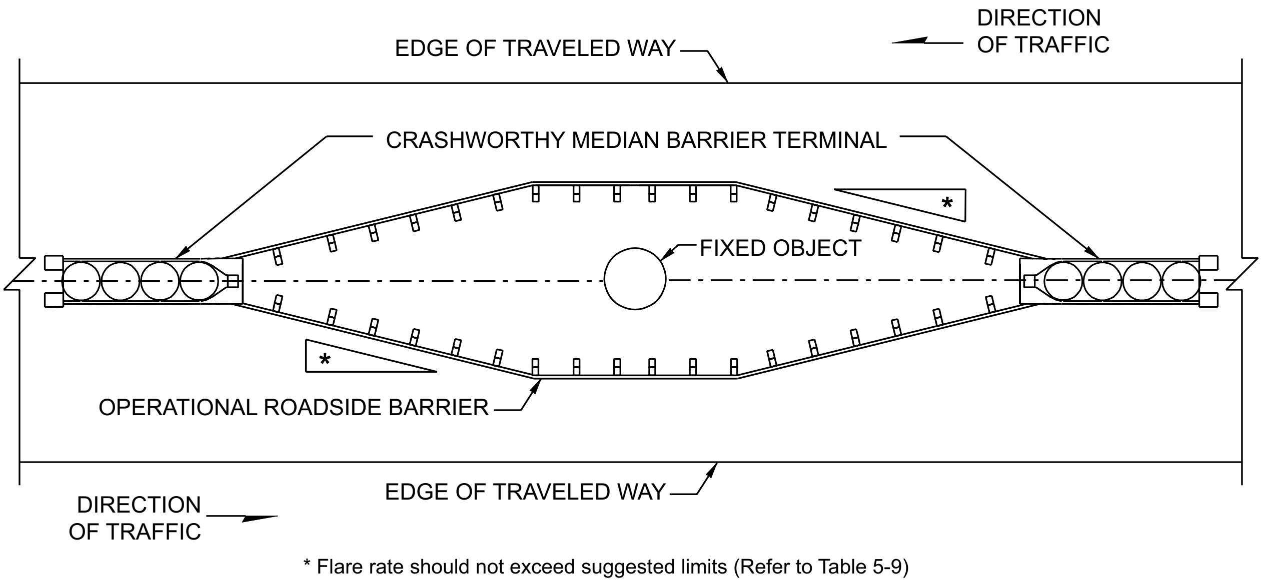

Figure 6-20. Suggested Layout for Shielding a Rigid Object in a Median

6.7 UPGRADING SYSTEMS

Some existing median barriers do not meet suggested performance levels. Older barriers usually fall into one of two categories: those that have structural inadequacies or those that are functionally inadequate.

Section 5.7.1 provides guidance for evaluating the structural adequacy of roadside barriers. The same factors can be applied to median barriers. Persons inspecting existing installations should stay abreast of current traffic barrier designs and guidelines as well as promising new research findings. Of course, there is no substitute for field data or crash records to evaluate the performance of a system.

States are encouraged to adopt policies that consider modification or replacement of barrier systems that do not meet current guidelines. It is recognized that this action is not always cost-effective; therefore, decisions about treatment of existing systems should be based on a case-by-case analysis considering upgrade costs, repair and maintenance costs, and potential crash frequency and severity. Table 5-9 also may be used to evaluate the functional adequacy of existing barriers. If the barrier is placed in a depressed median or a median with surface irregularities, it may not function properly. If improperly located, corrective measures should be considered. If necessary, the barrier can be moved near the shoulder's edge or returned to a position in which the approach terrain to the barrier is no steeper than the criteria suggest. Another possible solution would be to extend the shoulder to the lateral distance desired and place the barrier on the shoulder. Steep flare rates for approach and transition sections should be flattened to conform to the criteria recommended in Table 5-9.

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Chapter 7
Bridge Railings and Transitions

7.0 OVERVIEW

A *bridge railing* is a longitudinal barrier intended to prevent a vehicle from running off the edge of a bridge or culvert. Bridge railings are normally constructed of a metal or concrete post-and-railing system, a concrete safety shape, or a combination of metal and concrete. Most bridge railings differ from roadside barriers in that bridge railings are an integral part of the structure (i.e., physically connected) and usually are designed to have virtually no deflection when struck by an errant vehicle.

This chapter summarizes the performance and structural requirements of each of the six test levels defined in *NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features (13)* and *Manual for Assessing Safety Hardware* (MASH) *(3)* for bridge railings. It also addresses selection and placement guidelines for new construction and includes examples of some typical retrofit designs for older bridges with substandard railings. Finally, it addresses bridge railings and roadside barriers as a complete system and provides general information on appropriate transition sections between the two barrier types.

The information presented here is intended only to summarize selected sections of the current *Standard Specifications for Highway Bridges (1)* and the *AASHTO LRFD Bridge Design Specifications (2)* from the American Association of State Highway and Transportation Officials (AASHTO). Detailed information on analytic design procedures for test rail specimens, design loadings, and materials specifications can be found in those documents.

7.1 PERFORMANCE REQUIREMENTS

The *AASHTO Standard Specifications for Highway Bridges* requires that bridge railings meet specific geometric criteria and be capable of resisting applied static loads without exceeding design requirements in any of their component members. The Federal Highway Administration (FHWA) requires all bridge railings used on the National Highway System (NHS) to be a crash-tested design.

The *AASHTO LRFD Bridge Design Specifications* provide the most current guidance on performance requirements of railings for new bridges and for rehabilitated bridges to the extent that railing replacement is determined to be appropriate. NCHRP Report 350 crash test criteria were used to develop the design criteria in the *AASHTO LRFD Bridge Design Specifications*.

Existing bridge railings designed to criteria in the *AASHTO Standard Specifications for Highway Bridges* and those crash tested under previous guidelines may be acceptable to use on new or reconstruction projects through evaluation of their in-service performance. For existing bridge rails, individual states should develop a guideline for retention, upgrading, or both for the in-place rails based on a safe, cost-effective approach. See Section 7.7 for additional guidance or comparative analysis.

7.2 GUIDELINES

A bridge railing should be chosen to satisfy the site-specific conditions as completely as possible while being practical. Refer to Section 13 of the *AASHTO LRFD Bridge Design Specifications* for information on developing guidelines.

A rigid railing requires approach guardrail and a transition section between barrier types. This full treatment may not be cost-effective on bridge-length culverts, and alternate treatments should be considered. Such treatments could include extending the structure and leaving the edges unshielded or using a less expensive, semi-rigid type railing.

When a bridge also serves pedestrians, cyclists, or both, a barrier to shield them from vehicular traffic may be required. The need for a pedestrian or cyclist railing should satisfy the site-specific conditions as completely as possible while being practical.

7.3 APPROPRIATE TEST LEVEL SELECTION CONSIDERATIONS

As with other traffic barriers, the current design criteria for bridge railings relate primarily to standard size automobiles and pickup trucks, resulting in the selection of a design meeting NCHRP Report 350 Test Level 3 (TL-3). Test requirements are the same for a bridge rail as those for a longitudinal barrier, previously described in Chapter 5. Section 5.3 lists the subjective factors most often considered in selecting an appropriate test level for traffic barriers, including bridge railings, at a specific location.

Several state highway agencies and the FHWA have recognized that it may be desirable in certain situations to design and install railings that can contain and redirect heavy vehicles such as buses and trucks *(10)*. Although penetration of any railing by a vehicle is potentially hazardous to its occupants, locations where vehicular penetration of a railing system could be particularly hazardous to others as well should be given careful evaluation before deciding on the type of railing to install.

A second concern that must be considered in selecting a high-performance railing is its effective height. A railing may have adequate strength to prevent physical penetration, but unless it also has adequate height, an impacting vehicle or its cargo may roll over the railing or onto its side away from the railing after redirection. Also, sight distance should be investigated when needed.

In addition, the shape of the face of the railing may have a significant effect on its performance. Various safety shapes have been successfully tested in accordance with NCHRP Report 350 criteria. A safety-shaped railing can cause a large vehicle to roll up to 24 degrees before it contacts the upper edge of the railing. Thus, a vertical face may be more desirable when heavy vehicle rollover is a primary concern.

Another concern is about the placement locations and the types of hardware attachments on or adjacent to bridge rails. Those hardware attachments may consist of pedestrian and bicycle railings, breakaway and non-breakaway sign supports, luminaire poles, large sign support structures, sound walls, various types of fences, and decorative features. Review of bridge rails that have been impacted by large trucks and other high center-of-gravity vehicles has revealed that the vehicles may lean over and extend past the top of the bridge rail. The clear area that should be provided behind a bridge rail and beyond its dynamic deflection distance to account for this behavior is called the Zone of Intrusion (ZOI). Hardware attachments placed in these areas should be avoided when practical. Some attachments could be potential vehicular snagging hazards. Attachments placed on bridges at sensitive sites such as overpasses where debris could fall on or into the paths of roadway traffic below them should be avoided unless the attachments are placed outside of the ZOI. For more information regarding zone of intrusion, refer to Chapter 5 and the Transportation Research Board's (TRB's) *Guidelines for Attachments to Bridge Rails and Median Barriers (11)*.

7.4 CRASH-TESTED RAILINGS

In the past, the crash test matrix for bridge railings has differed from those used for other longitudinal barriers. Under MASH, a uniform crash test matrix is used for all longitudinal barriers, including bridge rails. All new tests for bridge railings should be in accordance with the guidelines in MASH. Table 7-1 shows the MASH crash test matrix for bridge railings *(3)*.

Table 7-1. MASH Test Matrix for Bridge Railings *(3)*

Test Level (TL)	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg [lbs]	**Speed km/h [mph]**	**Angle Degrees**
1	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	50 [31] 50 [31]	25 25
2	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	70 [44] 70 [44]	25 25
3	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	100 [62] 100 [62]	25 25
4	1,100C (Passenger Car) 2,270P (Pickup Truck) 10,000S (Single-Unit Truck)	1,100 [2,420] 2,270 [5,000] 10,000 [22,000]	100 [62] 100 [62] 90 [56]	25 25 15
5	1,100C (Passenger Car) 2,270P (Pickup Truck) 36,000V (Tractor–Van Trailer)	1,100 [2,420] 2,270 [5,000] 36,000 [79,300]	100 [62] 100 [62] 80 [50]	25 25 15
6	1,100C (Passenger Car) 2,270P (Pickup Truck) 36,000T (Tractor–Tank Trailer)	1,100 [2,420] 2,270 [5,000] 36,000 [79,300]	100 [62] 100 [62] 80 [50]	25 25 15

The FHWA maintains a list of designs that recently have been crash tested in accordance with one of the test levels defined in NCHRP Report 350 or MASH, as well as a list of designs previously tested under earlier guidelines that have been assigned an NCHRP Report 350 equivalent test level.

A complete list of crash-tested bridge railings may be obtained from the FHWA Office of Highway Safety through its website (http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/) as well as the online guide for bridge rail systems and transition systems through the AASHTO–AGC–ARTBA Joint Committee Task Force 13 website (http://www.aashtotf13.org).

The requirements in Chapter 13 of the *AASHTO LRFD Bridge Design Specifications* should be used for the design of crash-tested railing test specimens and the design of bridge deck overhangs. These specifications do not apply to connections of bridge barriers to deck materials other than concrete (e.g., fiber-reinforced polymer [FRP], steel).

All newly developed bridge railings should be successfully crash tested in accordance with MASH. To minimize duplicate crash testing, the FHWA may allow the use of bridge rail designs that are similar to a crash-tested design based on an analytic comparison by using the methodology outlined in Section 13 of the *AASHTO LRFD Bridge Design Specifications*. FHWA policy and an example comparison prepared by the Colorado Department of Transportation (CDOT) are contained in a May 16, 2000, memorandum at the following website: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/index.cfm.

For illustrative purposes, this section contains brief descriptions and photographs of some of the bridge railings that meet the crash test requirements of the six test levels defined in NCHRP Report 350 or MASH.

7.4.1 NCHRP 350 TL-1 through TL-4 Bridge Railings

TL-1 bridge railings typically are used on low-speed roadways and temporary work zone applications. As a result, only a few bridge railings have been designed and tested in accordance with TL-1. The Curb Type Glu-Lam Timber Railing, shown in Figure 7-1, is one such example.

The Texas T-6 Railing, shown in Figure 7-2, is an example of a TL-2 bridge railing.

The Wyoming Two-Tube Bridge Railing, shown in Figure 7-3, has been crash tested according to NCHRP Report 230 TL-2 guidelines *(12)*. It was subsequently approved as a TL-3 bridge railing under the NCHRP 350 criteria. Many concrete post-and-beam bridge railings also meet the TL-3 crash test requirements.

Several bridge railings have been successfully crash tested in accordance with the NCHRP 350 TL-4 criteria. The 813-mm [32-in.] high concrete F-shaped bridge railing, shown in Figure 7-4, is a typical example of a concrete TL-4 bridge railing. Steel bridge railings also have been crash tested in accordance with the NCHRP 350 TL-4 criteria. In testing under the MASH criteria, the 813-mm [32-in.] New Jersey concrete safety-shaped barrier was successfully crash tested in accordance with TL-3 requirements.

Figure 7-1. Curb Type Glu-Lam Timber Railing

Figure 7-2. Texas T-6 Railing

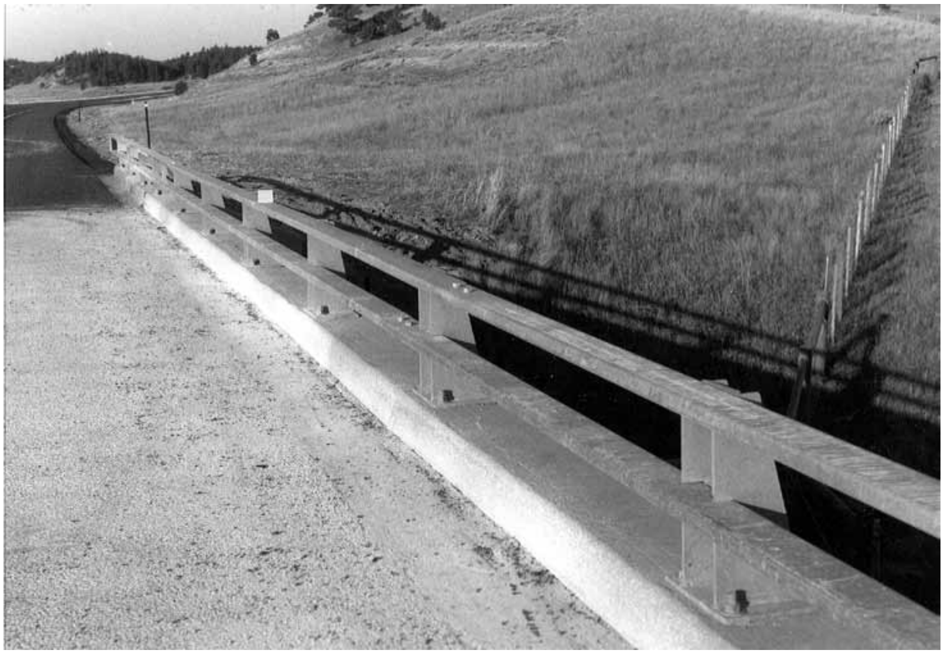

Figure 7-3. Wyoming Two-Tube Bridge Railing

Figure 7-4. Concrete F-Shaped Bridge Railing

7.4.2 MASH TL-5 and TL-6 Bridge Railings

All current solid concrete barriers (i.e., New Jersey and F-shapes, single-slope, and vertical wall) are considered to be MASH TL-5 bridge railings when adequately reinforced and built to a minimum height of 1,067 mm [42 in.]. Figure 7-5 shows a 1,067 mm [42 in.] high concrete safety-shaped bridge railing, which is a common bridge railing used on new construction. The concrete barrier requires virtually no maintenance for most hits. The Texas Type Tank Truck (TT), shown in Figure 7-6, is an extremely strong bridge railing that meets the MASH TL-6 crash test requirements.

Figure 7-5. 1,067-mm [42-in.] Tall Concrete Safety-Shaped Bridge Railing

Figure 7-6. Texas Type TT Railing

7.5 SELECTION GUIDELINES

Five factors should be considered in selecting a bridge railing: (1) performance, (2) compatibility, (3) cost, (4) field experience, and (5) aesthetics. Despite the relative importance placed on these factors, the capability of a railing to contain and redirect the design vehicle should never be compromised. In addition, using protective screens at overpasses when deemed necessary also should be considered.

7.5.1 Railing Performance

Bridge railings should be installed based on the Owner's recommendations. As a minimum, TL-3 bridge railings should be used on the NHS (including Interstate and major highways routes as identified by FHWA) in accordance with FHWA policy *(9)*, summarized as follows: