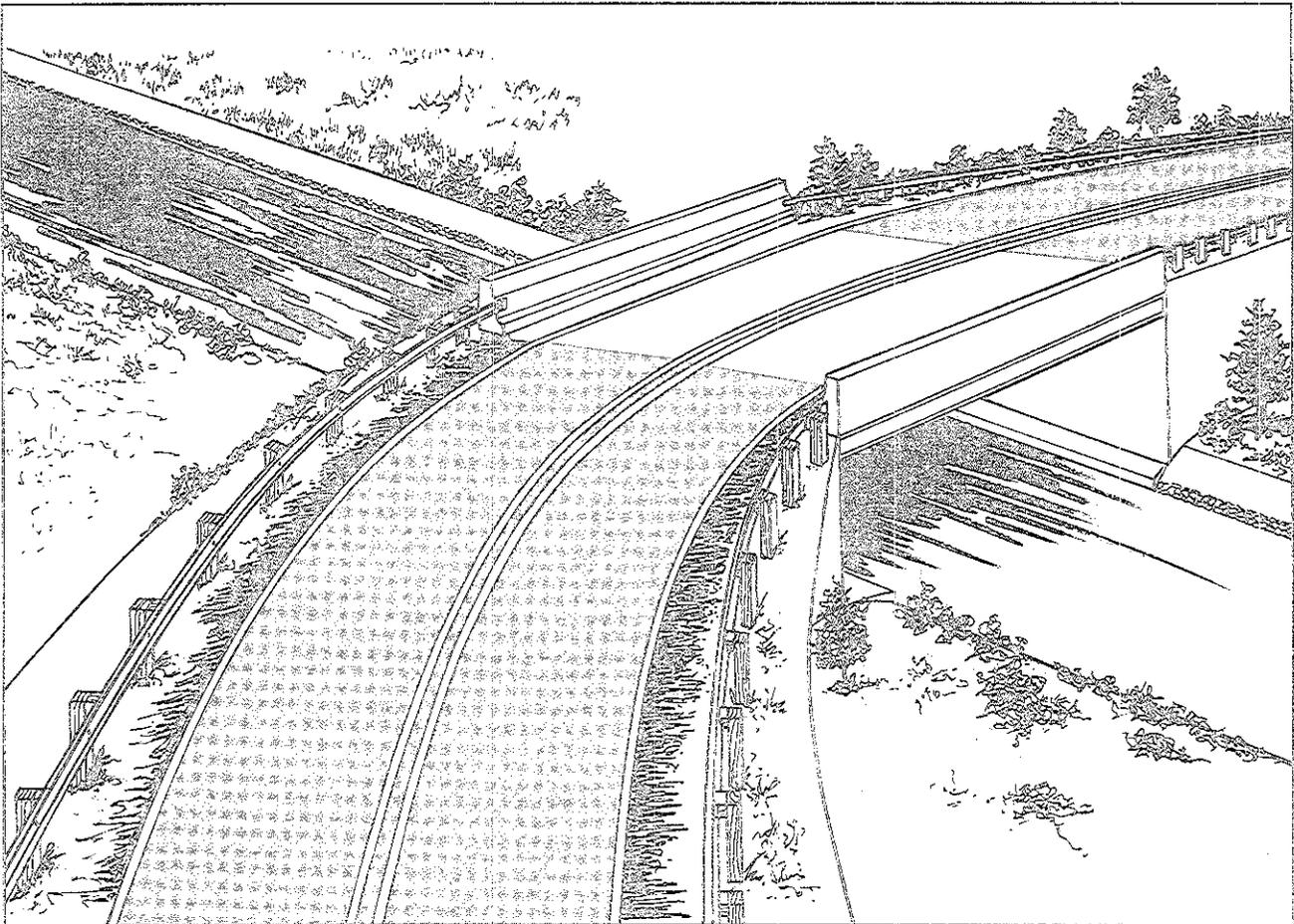


IMPROVING HIGHWAY SAFETY AT BRIDGES ON LOCAL ROADS AND STREETS

October 1998



Local Technical Assistance
Program (LTAP)



U.S. Department of Transportation
Federal Highway Administration

IMPROVING HIGHWAY SAFETY AT BRIDGES ON LOCAL ROADS AND STREETS

Prepared by:

Federal Highway Administration

Office of Highway Safety
Office of Engineering

NOTICE

The contents of this pamphlet do not reflect the official views or policy of the Federal Highway Administration (FHWA). The FHWA does not endorse particular products or manufacturers. This pamphlet does not constitute a standard, specification, or regulation. It is intended as a general guide to effective, low cost methods of improving roadside safety. Detailed technical information on the subjects covered in this pamphlet is available through the state highway agency or the FHWA Division Offices or through Technology Transfer Centers.

Foreword

This publication was developed by the Federal Highway Administration's Office of Highway Safety and has been produced by the FHWA's Local Technical Assistance Program (LTAP) for distribution through the LTAP Center network to the local, tribal, and rural governments.

The Federal Highway Administration's Local Technical Assistance Program is a network of 57 centers nationwide. The purpose of the LTAP is to stimulate the progressive and cost-effective transfer of highway technology and technical assistance to local, tribal, and rural governments. The LTAP accomplishes this by funding a variety of activities and projects that link local highway agencies, tribal governments, the States, universities and the Federal Government. The LTAP brings transportation technology transfer services, products, and educational resources to the local level. LTAP centers are located in each State and Puerto Rico. Six additional centers assist American Indian Tribal governments.

While each of the LTAP centers has the flexibility to tailor its program to the needs of local customers, there are six basic requirements that are common throughout the entire network. The requirements are: (1) each center must publish a quarterly newsletter; (2) distribute technology transfer materials; (3) provide an information service; (4) provide at least ten training courses; (5) evaluate the effectiveness of the program and; (6) compile and maintain a mailing list of tribal, local, and rural officials having transportation responsibilities.

The centers use a mix of technology transfer tools and marketing activities to meet its customer needs. Some typical endeavors include: training workshops; on site demonstrations and "hands on" training; "road shows" or circuit-rider programs that take training on the road; microcomputer software development; adaptation and distribution of technical publications and user manuals; studies on specialized topics; lending libraries for videos, publications, and other such materials.

To learn more about the Local Technical Assistance Program and what it can do for you or to provide suggestions for program improvement please contact your nearest LTAP Center, the FHWA State and Local Programs Team, or the LTAP Clearinghouse at the phone numbers shown below:

LTAP Clearinghouse: (202) 347-7267; Internet: <http://www.ltap2.org>
FHWA State and Local Programs Team: (202) 366-4675 / 9633

Center Phone Numbers

Alabama:	(334) 844-4320	Massachusetts:	(413) 545-2604	South Carolina:	(864) 656-3000
Alaska:	(907) 451-5320	Michigan:	(906) 487-2102	South Dakota:	(605) 688-4185
Arizona:	(602) 256-9431	Minnesota:	(612) 625-5829	Tennessee:	(423) 974-5255
Arkansas:	(501) 569-2249	Mississippi:	(601) 968-2339	Texas:	(409) 845-4457
California:	(510) 231-9590	Missouri:	(573) 751-0852	Utah:	(801) 797-2931
Colorado:	(970) 221-9309	Montana:	(800) 541-6671	Vermont:	(802) 654-2652
Connecticut:	(860) 486-5400	Nebraska:	(402) 472-5748	Virginia:	(804) 293-1966
Delaware:	(302) 739-3267	Nevada:	(702) 784-1433	Washington:	(360) 705-7390
Florida:	(352) 392-2371	New Hampshire:	(603) 862-2826	West Virginia:	(304) 293-3031
Georgia:	(404) 656-5364	New Jersey:	(908) 932-3640	Wisconsin:	(608) 262-0422
Hawaii:	(808) 832-3405	New Mexico:	(505) 246-6420	Wyoming:	(800) 231-2815
Idaho:	(208) 885-4335	New York:	(607) 255-8033		
Illinois:	(217) 785-5048	North Carolina:	(919) 515-8899	Native American LTAP Centers	
Indiana:	(765) 494-2164	North Dakota:	(701) 231-7051	California:	(916) 758-2442
Iowa:	(515) 294-8103	Ohio:	(614) 292-2871	Colorado:	(800) 262-7623
Kansas:	(913) 864-5658	Oklahoma:	(405) 744-6049	Michigan:	(906) 487-3164
Kentucky:	(800) 432-0719	Oregon:	(503) 986-2854	Montana:	(406) 994-6100
Louisiana:	(504) 767-9117	Pennsylvania:	(717) 772-1972	Oklahoma:	(405) 744-6049
Maine:	(207) 287-2152	Puerto Rico:	(787) 834-6385	Washington:	(509) 358-2230
Maryland:	(301) 405-2009	Rhode Island:	(401) 277-1235		

This pamphlet is intended as a general guide to effective, low-cost methods of improving and enhancing bridge and bridge approach safety. It is not a design manual or a substitute for engineering knowledge, experience, or judgement. Technical safety information such as bridge standards, crash-worthy approach rail systems and their attachment to the bridge rail, highway and bridge width, and development of highway alignments can be found in the material listed in the references. The guidance and information included in this pamphlet are based on actual situations and common existing bridge and roadway features identified through national reviews. Some of the information provided in this pamphlet reflects a type of cost-effective improvement that can be made as a temporary measure before a bridge and/or bridge approach is reconstructed to current standards.

Nationally bridges and bridge approaches have been identified as one of the leading locations for severe, single-vehicle crashes. There are many bridges and large culverts on the highway system. Most have rigid rails and often span a potentially hazardous feature. Many of these structures were built decades ago for highways of lower speed and less traffic. Because of the high cost of replacing bridges and the long service life of many bridges, replacement of the bridge or major component of a bridge, such as the bridge deck or bridge rails, may not be a priority while the bridge remains structurally adequate. In situations where it is considered inappropriate to reconstruct the bridge or some element of the bridge to current standards, temporary improvements, while not resolving a substandard condition, can significantly contribute to improving highway safety.

A temporary safety improvement may be considered when work is done to improve the safety or reduce the potentially hazardous nature of components or features of the bridge or roadway approaching the bridge. A safety improvement is considered temporary when it doesn't fully satisfy current design standards, but provides a significant improvement over existing conditions to warrant its application until the bridge and/or the approach roadway can be reconstructed to current design standards. Temporary improvements are not considered substitutes for design standards and should not be used as a substitute or justification for delaying rehabilitation of a bridge and/or bridge approach.

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Introduction (Bridge Rails)

Bridge Rail Safety is Critical. Over the past two decades there have been considerable developments that improved the safety of the traveling public on and approaching bridges. During this time an extensive effort was made to determine which bridge rails were both structurally and functionally adequate.

It is often easier to evaluate how satisfactory an older bridge rail is by considering both its structural characteristics (strength) and its functional characteristics (how a car may behave in a crash).

Structural Adequacy is the ability of a bridge rail to withstand and redirect the impact of a vehicle, in most cases the design vehicle was a large passenger vehicle. In special situations the design vehicle could be a bus or truck; however, on local roads and streets, it was almost always a large passenger vehicle.

Functionally Adequate is the ability of a bridge rail to function as a safe barrier system. There are two different safety characteristics associated with functional adequacy.

First, a bridge must be as wide or wider than the roadway. This means the width of the bridge between the bridge rails is the same or greater than the highway lanes and shoulder widths. The bridge is at least as wide as the roadway.

Second, the bridge rail must safely redirect an impact car without:

1. Redirecting the car into the opposite side bridge rail or into opposing traffic.
2. Snagging the car and causing abrupt deceleration, rotation (turning sideways) into the flow of traffic or instability and overturning.
3. Vaulting the car over the bridge rail or causing it to overturn, or
4. Penetrating into the passenger compartment (some part of the bridge rail detaching and going inside the car passenger compartment).

Simply put, the bridge rail must be crash worthy.

Introduction (Approach Guardrail)

The Bridge Approach Guardrail System is also an important component of bridge safety.

Functional adequacy of the guardrail system at the bridge approaches is just as important as bridge rail safety. As bridge rails developed and became safer so did the guardrail systems and crash cushions that are used at bridge approaches. Many special features have been developed for guardrail approaches to bridges to ensure they are both structurally and functionally adequate.

Structural Adequacy is the ability of a guardrail system to withstand the impact of a crash and redirect the impact of a car without separating and allowing the car to pass through, or deflecting into the bridge rail and causing the car to snag.

To be structurally adequate at the bridge approach, a guardrail must be:

1. Adequately connected to the bridge rail or approach parapet. The guardrail must not separate from the bridge rail in a crash.
2. Adequately supported in the transitional section between the guard rail and the bridge rail. Often this is done by using larger and/or additional posts, and sometimes, when there isn't sufficient soil support, longer posts. The guard rail must not deflect or lean over in a crash.

Functionally Adequate is the ability of the approach guardrail system to function as a safe barrier system and smoothly redirect an impacting car without causing it to stop abruptly, snag, roll over or vault over the guardrail.

First, to be functionally adequate an approach guardrail must be long enough to prevent a car from getting around it and driving into a hazard. This means the length of the approach guardrail or crash cushion is unique to the site conditions and can vary at each bridge. At some bridges the length of guardrail can even vary on each end of the bridge because of different conditions.

Second, the approach guardrail must safely redirect an impact car without:

1. Redirecting the car into the guardrail or bridge rail on the other side or into the opposing traffic lane.
2. Snagging the car or creating a pocket that can cause abrupt deceleration, rotation (turning sideways) into the flow of traffic or instability and overturning.
3. Vaulting the car over the guardrail or causing instability and overturning, or
4. Penetrating into the car's passenger compartment.

Simply put, the approach guardrail or crash cushion must be crash worthy, of sufficient length, and located properly to prevent a car from getting around it and into the hazard area.

Introduction

(Other Bridge Safety Considerations)

There are also other conditions that relate to bridge and bridge rail safety. These include, but are not limited to, improving safety at piers, abutments and other fixed objects, pedestrian and bicycle safety over the bridge, safety of the public passing under the bridge, freezing of bridge decks before the roadway, open joints (usually longitudinal joints are hazardous to motorcycles), drainage features and structural integrity of through trusses.

Remember, a bridge feature or feature associated with a bridge is considered potentially hazardous when it can cause a car to: 1) stop abruptly; 2) become unstable (overturning, snagging or vaulting); 3) penetrate through the bridge rail; 4) injure other individuals on, under or around the bridge; or 5) injure a motorist by penetrating into the passenger compartment.

Correcting, Improving, Enhancing or Mitigating Bridge Hazards

There are three primary areas in which safety can be improved or potentially hazardous features improved or mitigated at and around bridges. These include:

Bridge Improvements — Improvements to elements of the bridge structure or improvements that help mitigate potentially hazardous bridge features. They include improvements that can be made to a structurally or functionally inadequate bridge, such as improved bridge rails, sidewalks, open joints, deck surface (friction surface or pot holes), snag points on the bridge rail or bridge abutments, delineation of narrow bridges and strengthening of through truss members.

Bridge Approach Improvements — Improvements to the approach guardrail systems and roadway approaching the bridge. They include improvements to the guardrail alignment, transitioning the guardrail stiffness to meet the rigid bridge rail, connection of the guardrail to the bridge rail, drainage features, curbs and sidewalks.

Operational Improvements — Improvements to access points, signs, delineation, and pavement markings in the bridge approach area and on the bridge.

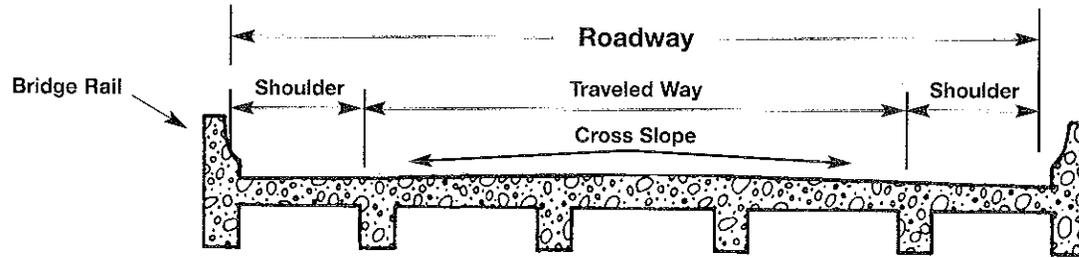
Definitions and Terms

Traveled Way	The portion of the roadway or bridge for the movement of motor vehicles (does not include shoulders, extra turning lanes, or sidewalks).
Roadway	The roadway is the traveled way plus the shoulders — it does not include sidewalks and extra turning lanes.
Approach Roadway	The approach roadway is the width of the standard section of roadway in the area of the bridge. It includes the traveled way and the full shoulder width. The approach roadway does not include the barrier offset distances or sidewalk widths.
Sidewalks	Sidewalks and exclusive bicycle paths are areas set aside for exclusive use of pedestrians and/or bicycles. They may be physically separate structures from the approach roadway and bridge, separated by a barrier, separated by a raised sidewalk or simply separated with pavement markings. These areas are not for motor vehicle use and are not considered part of the roadway width.
Guardrail Offset	The guardrail offset is the distance from the face of the guardrail to the outside edge of the shoulder. Guardrail offset allows most motorists full use of the shoulder while providing sufficient room to open car doors and exit a vehicle between the barrier and edge of shoulder.
Shoulder	The portion of the roadway next to the traveled way for the use by stopped motor vehicles and/or for emergency situations.
Hinge Point	The point on the roadway section where the slope rate changes.
Crash-worthy terminal	A crash-worthy guardrail terminal is a terminal that meets the criteria of the National Cooperative Highway Research Program, Report 230. The new NCHRP, Report 350, will replace the Report 230 on October 1, 1998.

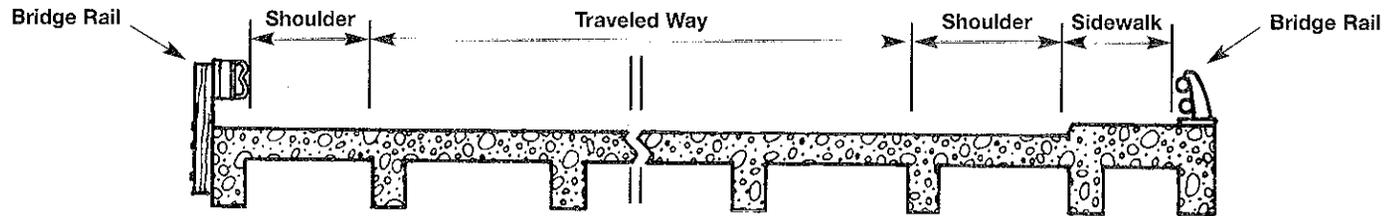
These features are shown on Figure 1.

Definition and Terms

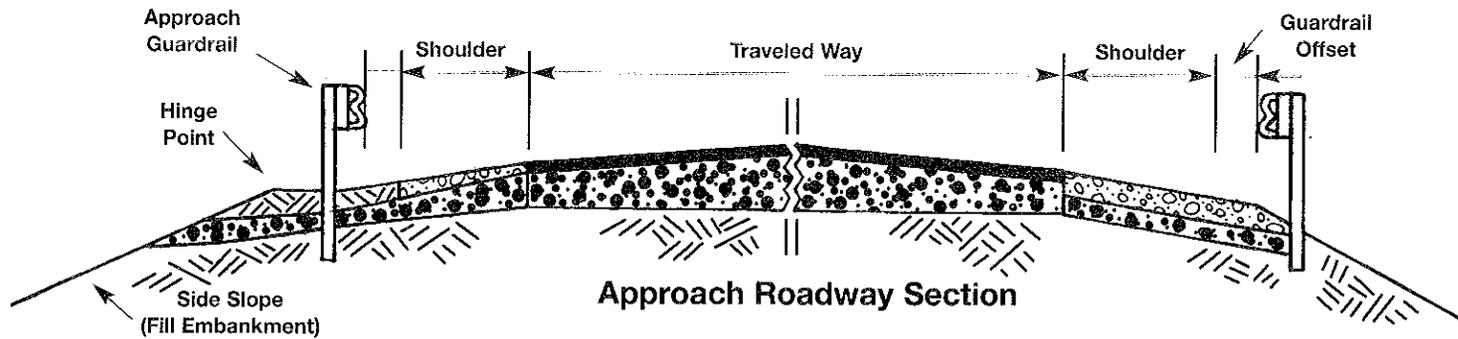
Bridge and Roadway Cross Section



Bridge Section



Alternative Bridge Sections



Approach Roadway Section

Figure 1.

Recognizing Inadequate Bridge Rail (Structurally Inadequate Bridge Rail)

A bridge rail must be strong enough to keep a car from going through it. This important characteristic of a bridge rail is called structural adequacy. A bridge rail is considered structurally adequate when it can sustain the theoretical impact of the design vehicle without allowing the vehicle to penetrate the bridge rail and safely redirect the vehicle. In almost all cases, the bridge rail on local streets and roads should be able to retain a large passenger car at the legal driving speed of the approach roadway. A bridge rail should retain its structural integrity and not require any major repair after a crash. The structural adequacy of a bridge rail is usually developed analytically and verified through crash testing. In common concrete bridge rails, it is a function of the width of concrete and the size, location and amount of reinforcing steel. The reinforcing steel is usually increased at the bridge rail ends to provide strong connections for the approach guardrail.

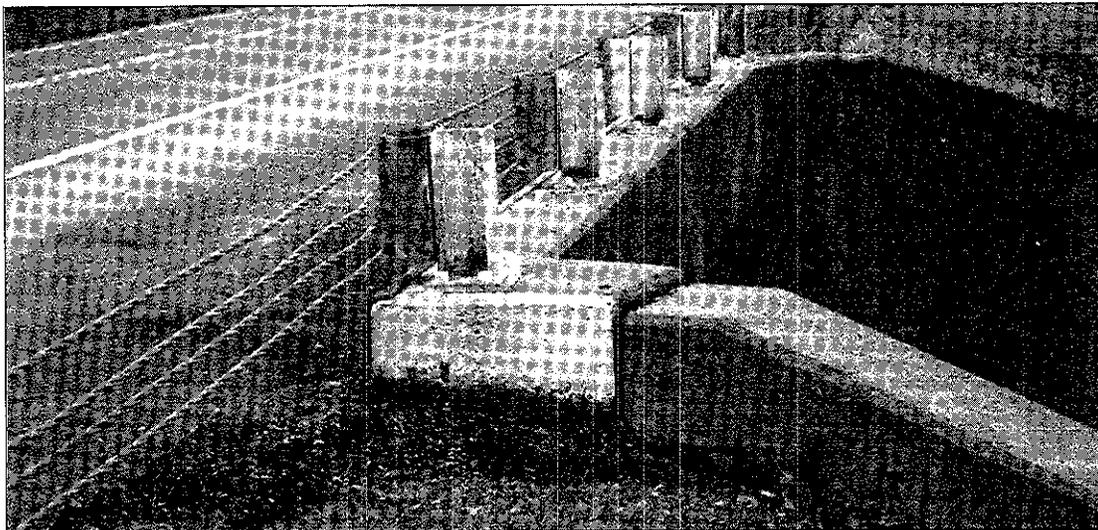
While it may be difficult to determine the structural adequacy of many older concrete bridge rails, there are some common types bridge rails that are easy to identify as structurally inadequate. The following photographs offer several examples of common structurally inadequate bridge rails.

Recognizing Inadequate Bridge Rail (Structurally Inadequate Bridge Rail)

Cable guardrail and all other flexible barrier systems are not considered adequate for use as a bridge rail or as a protective barrier over a large culvert in most situations. This is particularly true on higher speed/higher volume roads.

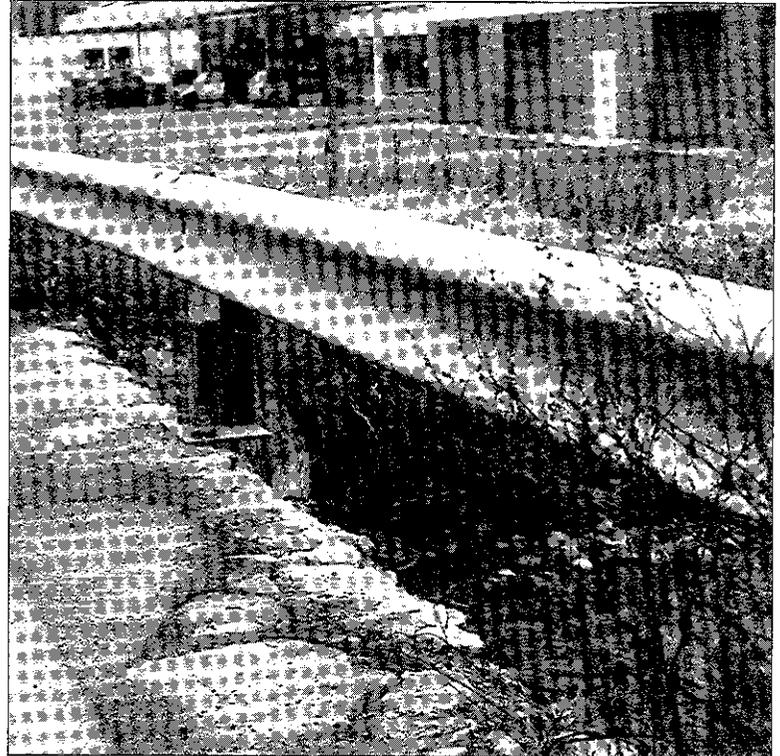
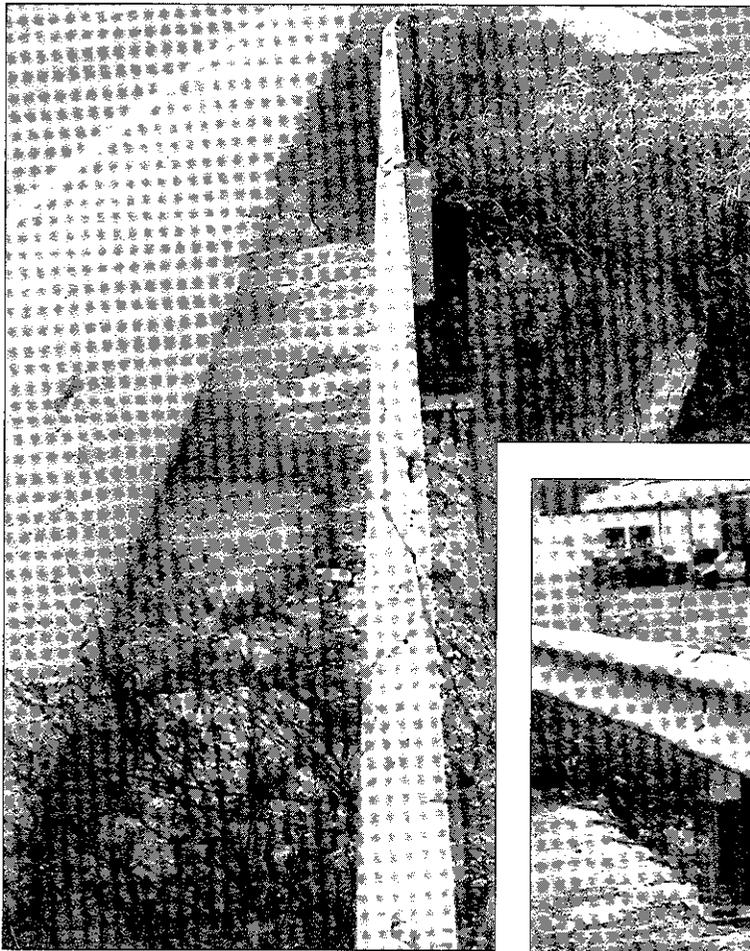
Guardrail systems may have been used as bridge rails. Many of these expedient bridge rails are not adequate for current highway conditions. Many of these bridge rails are made up of substandard guardrail components or they rely on bolts or other attachment devices that do not provide sufficient strength for a structurally adequate system. As shown in the illustration on page 9 the anchoring mechanisms for the posts have substantially deteriorated.

Cable systems, similar to the one shown below, can easily deflect and allow a car to go into the stream or strike the culvert wing walls. Additionally, a car approaching the bridge could hit the cable system and the deflecting cable could allow or direct the car either into the first post or into the stream.



Recognizing Inadequate Bridge Rail

Deterioration of the bridge rail, and the bridge deck in the area of the anchoring bolts or the bolts has occurred on many older bridges, particularly in areas where salts were used during the winter. The bridge rail shown below uses a substandard guardrail system (posts are spaced too far apart and there are no block outs between the posts and the “W” beam rail) and will not prevent the wheel of a car, even a slow moving car, from snagging on a post. The bridge rail shown below is structurally and functionally inadequate. The bridge deck concrete has deteriorated so much that only 50 percent of the post anchor bolts remain in concrete.



Recognizing Inadequate Bridge Rail (Functionally Inadequate Bridge Rail)

A bridge rail may be very strong but also be considered functionally inadequate when a car can:

- Vault over it, or
- Snag on it and be stopped or abruptly decelerated (causing the vehicle to become unstable resulting in a rollover or redirection of the vehicle into the rail on the other side of the bridge), or
- Be penetrated by part of the bridge rail (which can result in the death or injury of someone in the passenger compartment).

There are many factors that influence how bridge rails function. The current practice in developing a new bridge design is to crash test the design before building it. There are many current bridge rail designs in common use that have been crash tested and found crash worthy. The most common bridge rails are the concrete safety shape, the "F" shape (very similar to the safety shape) and the vertical wall. There are several steel bridge rail designs in common use. Information on the more common ones may be obtained through the references provided at the end of this pamphlet. There are also some retrofit bridge rail designs that have been crash tested successfully (see reference 2). Existing bridge rails should be reviewed for their structural and functional adequacy.

In many cases updating older bridge rails can be difficult and expensive, particularly when it requires replacing part or all of the bridge deck to provide for a crash worthy bridge rail. Bridge rail replacement projects that require extensive work are usually only done when it is also necessary to replace the bridge, the superstructure, or a major portion of the bridge deck.

When it may be impractical to update older bridge rail to current standards, it is generally easy to improve or enhance the safety of the bridge rail through interim improvement to the bridge rail, approach rail, or operational features associated with the bridge.

Recognizing Inadequate Bridge Rail (Vaulting features)

A bridge rail is considered inadequate when:

1. The bridge rail is not structurally adequate, and/or
2. The bridge rail or safety walk in front of the bridge rail can initiate vaulting of the vehicle over the rail (see Figure 2), and/or

Vaulting over a bridge rail can occur on higher-speed roads (40 mph and above) when a car hits a raised curb, drainage feature, or sidewalk, causing the car to become airborne. The car tire may then hit the bridge rail and continue to climb over it.

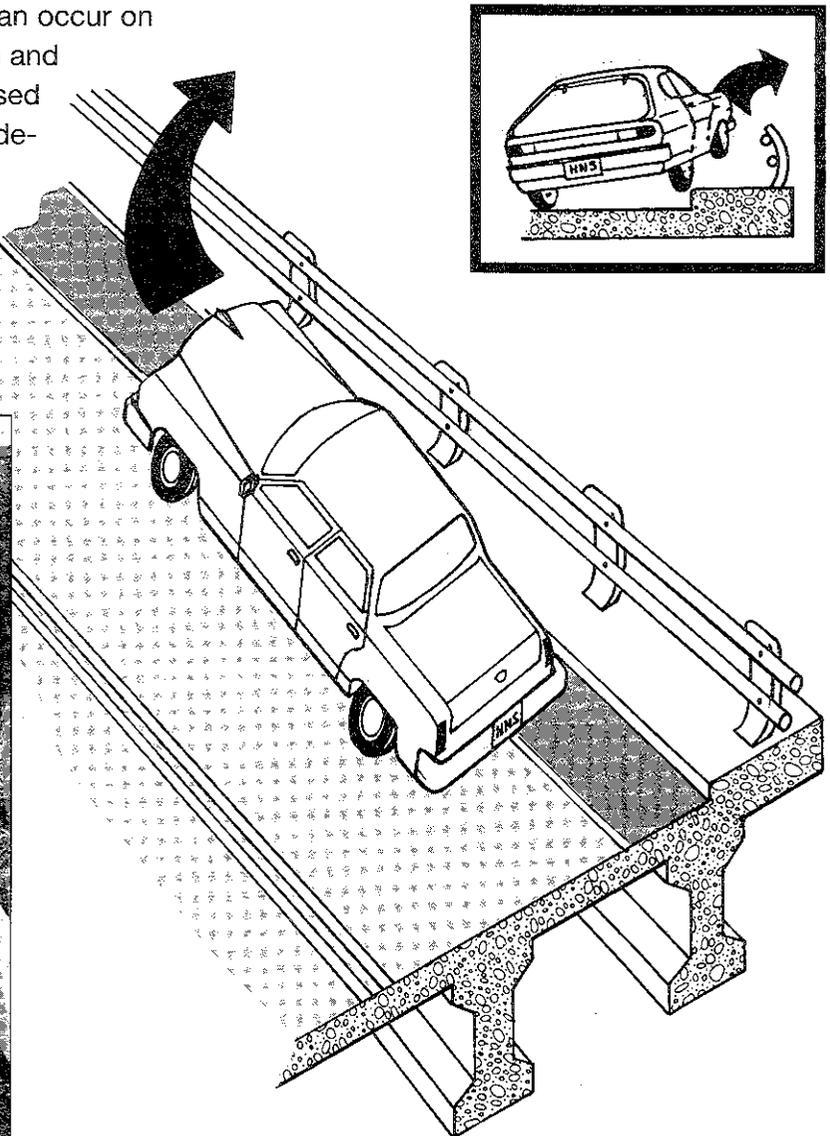
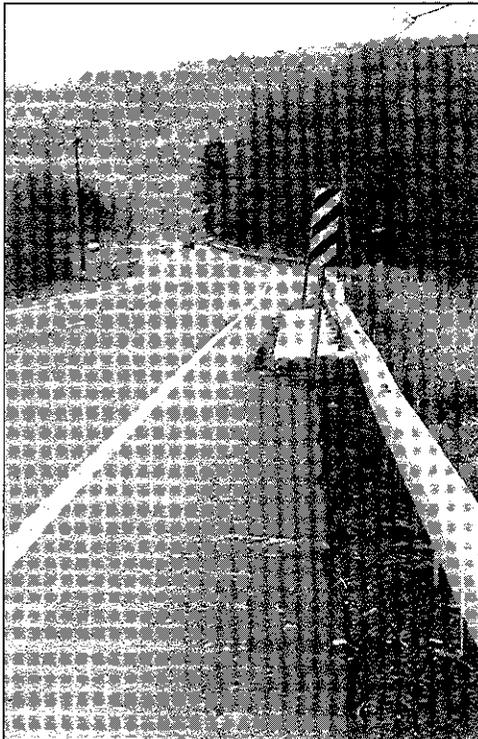


Figure 2.

Recognizing Inadequate Bridge Rail (Snagging Features)

3. The bridge rail can cause snagging, rapid deceleration, loss of stability or rotate the car sideways into the traffic lanes (see Figure 3), and/or

Snagging can occur when the bridge rail does not have a smooth continuous traffic face. Bridge rails with features that extend or are recessed more than 2 inches from the surface of the rail can cause a vehicle to snag. In addition, bridge rails that are not continuous over bridge joints and can deflect more than 2 inches in a crash can create a snag point.

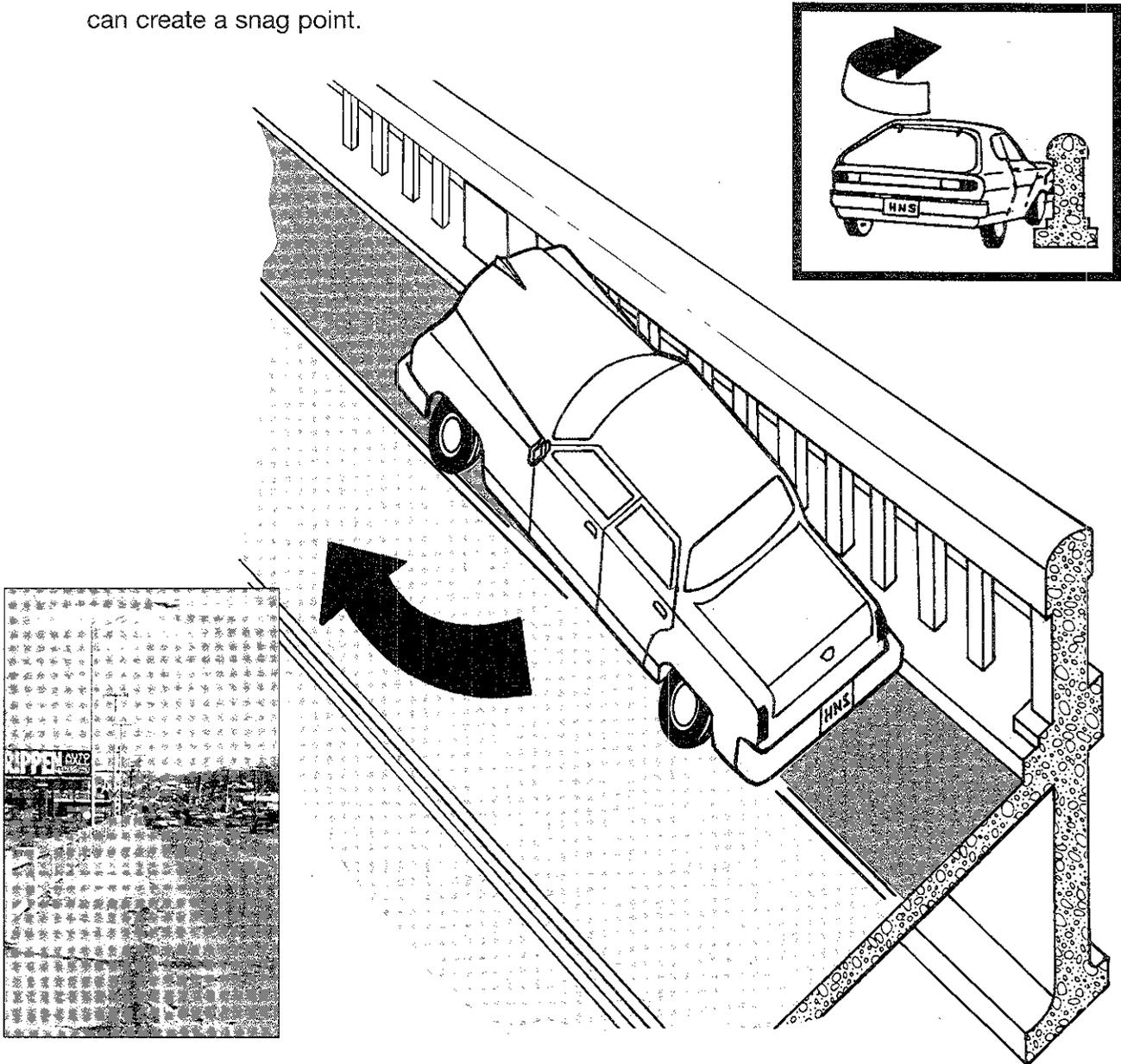
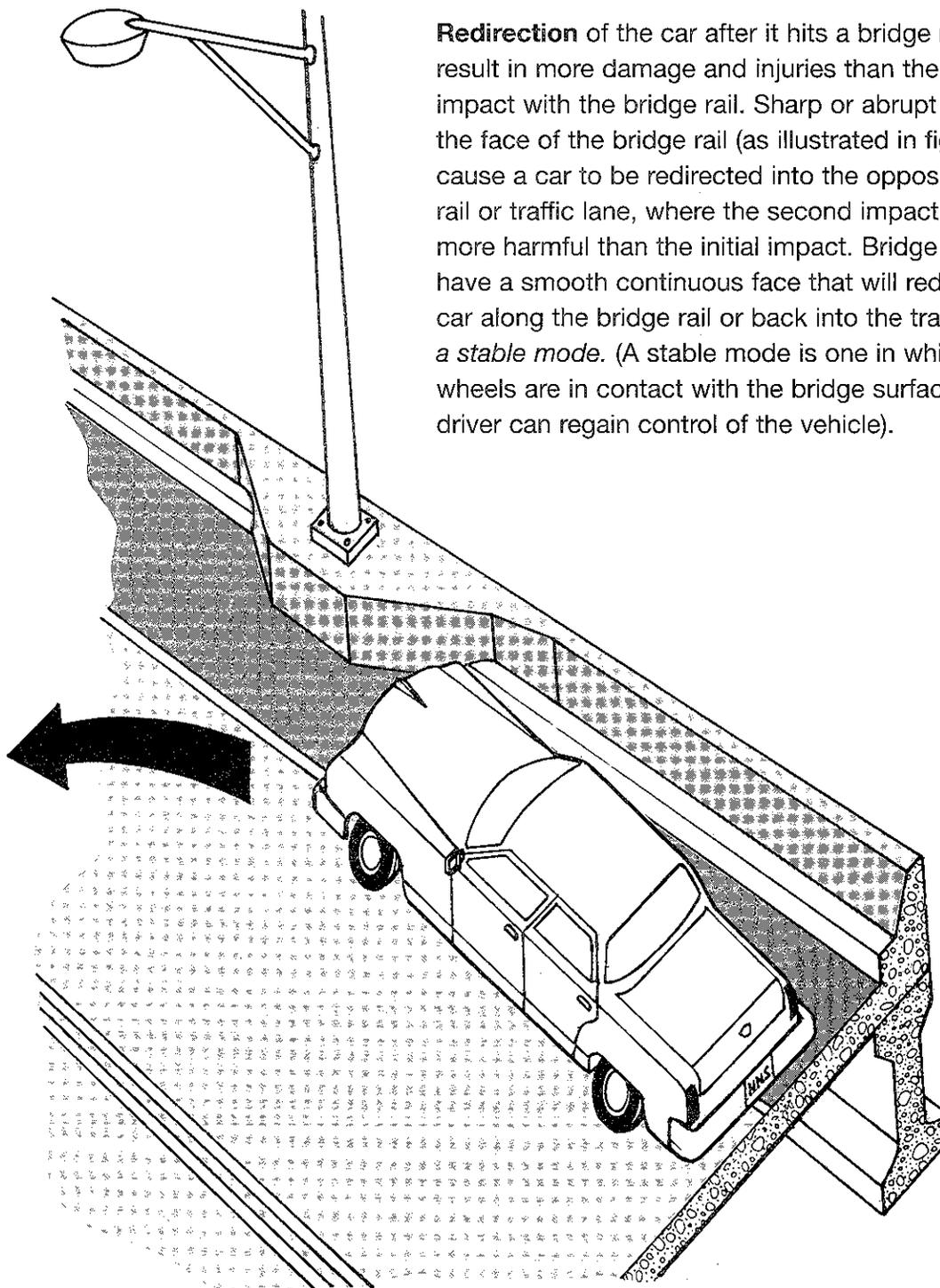


Figure 3.

Recognizing Inadequate Bridge Rail (Discontinuity in Shape of Bridge Rail)

4. The discontinuity of bridge rail shape can cause the car to be directed into the opposite rail or uncontrollably into opposing traffic (see Figure 4), and/or



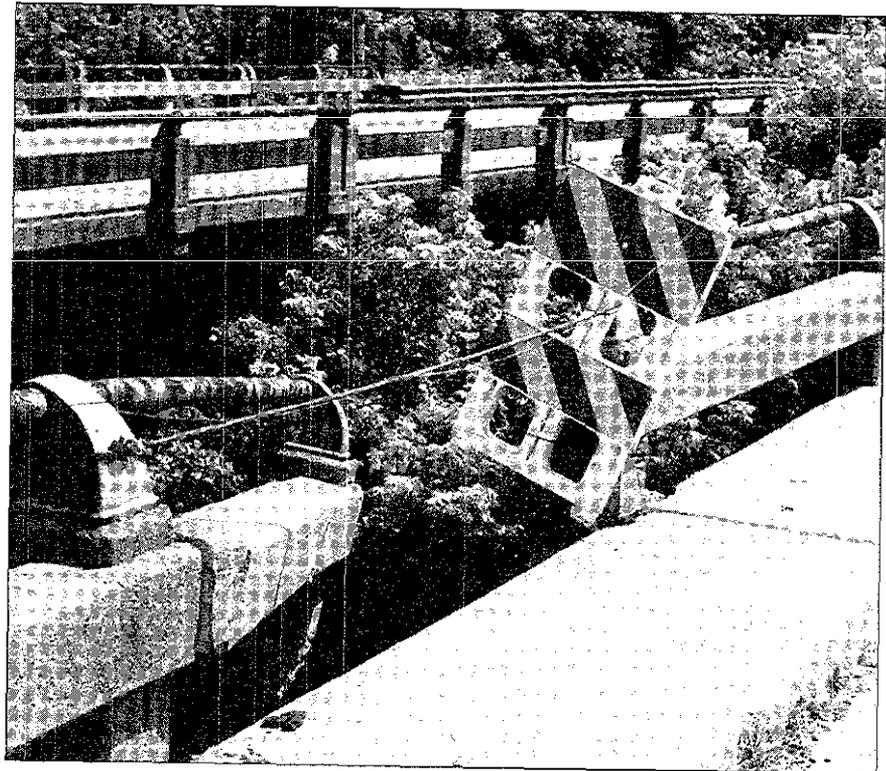
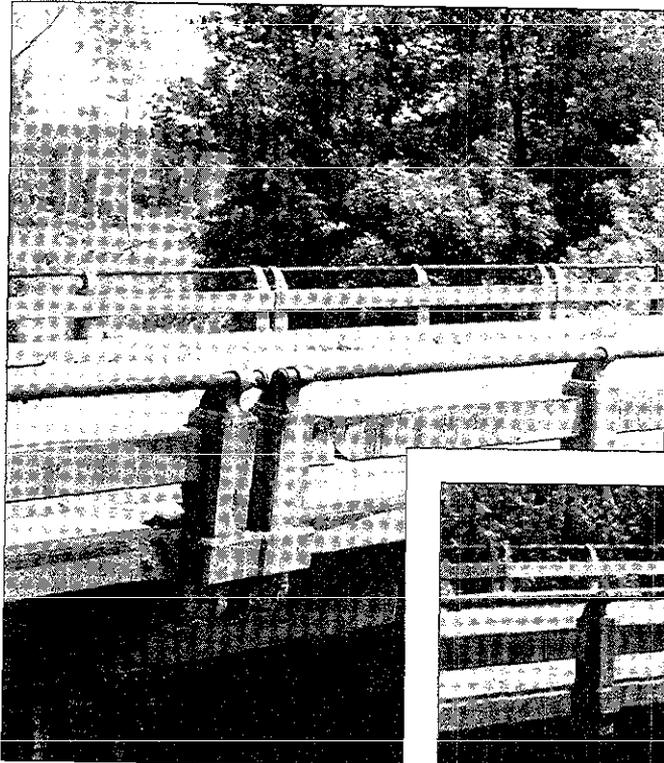
Redirection of the car after it hits a bridge rail can result in more damage and injuries than the initial impact with the bridge rail. Sharp or abrupt changes in the face of the bridge rail (as illustrated in figure 4) can cause a car to be redirected into the opposite bridge rail or traffic lane, where the second impact can be far more harmful than the initial impact. Bridge rails should have a smooth continuous face that will redirect the car along the bridge rail or back into the travel path *in a stable mode*. (A stable mode is one in which the car wheels are in contact with the bridge surface and the driver can regain control of the vehicle).

Figure 4.

Recognizing Inadequate Bridge Rail (Open Bridge Rail Joints and Unsecured Components)

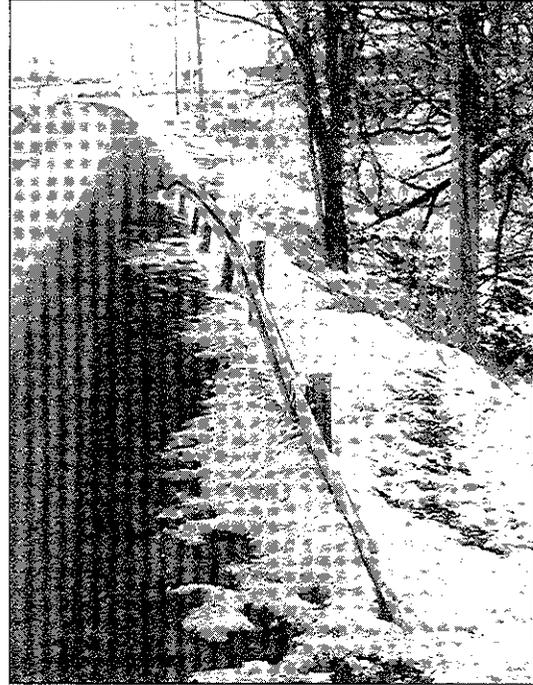
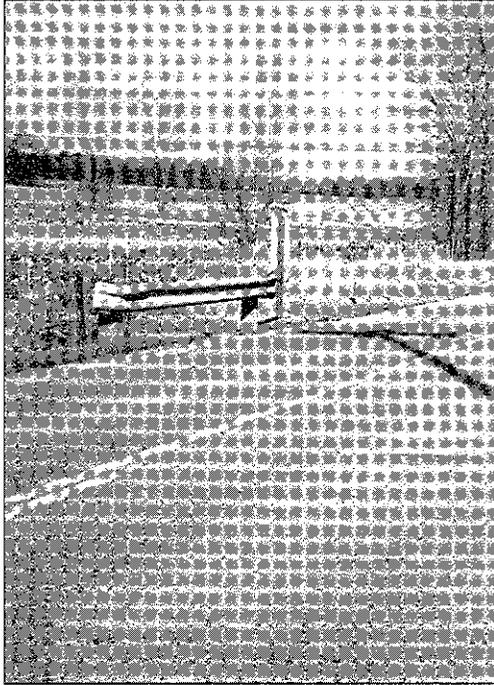
Open joints or unsecured bridge rail members can become dislocated in a crash so that a bridge rail element snags or penetrates the passenger compartment of the car. These components should be considered potentially hazardous.

Open joints, open spaces, or bridge rail members that are not continuously connected can either be knocked out of alignment by the impact of a car or become a spear when the bridge rail in front of it is knocked backward.



Recognizing Inadequate Bridge Rail (Common examples of Inadequate Bridge Rail)

The following pictures provide examples of common bridge or culvert rails on local roads and streets that are structurally and functionally inadequate.

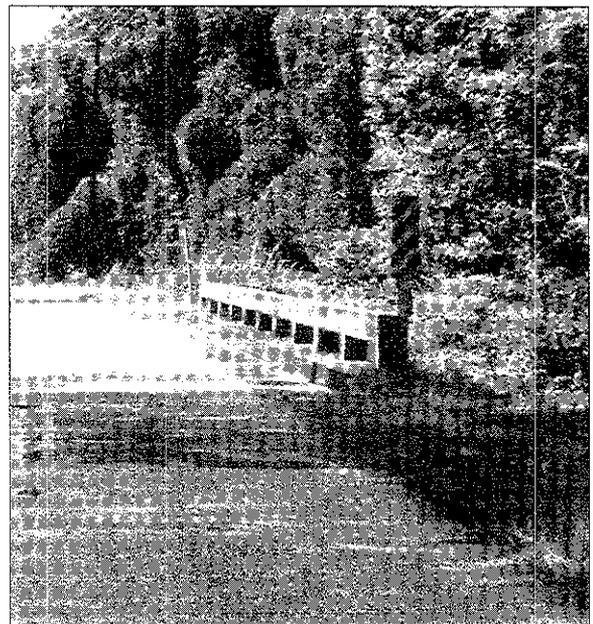
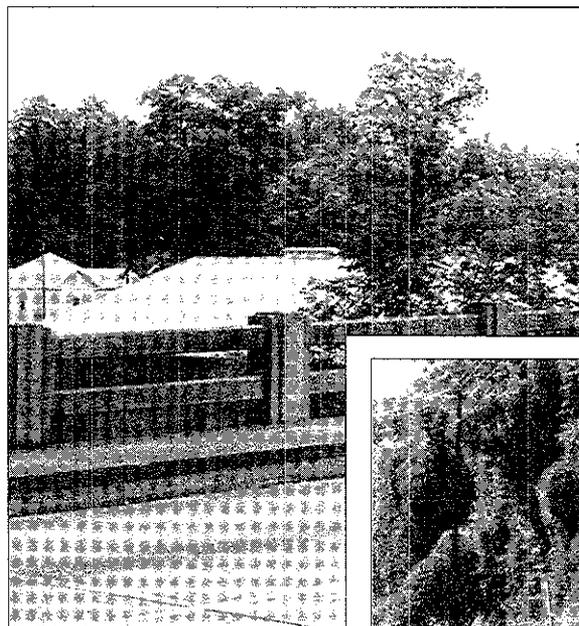
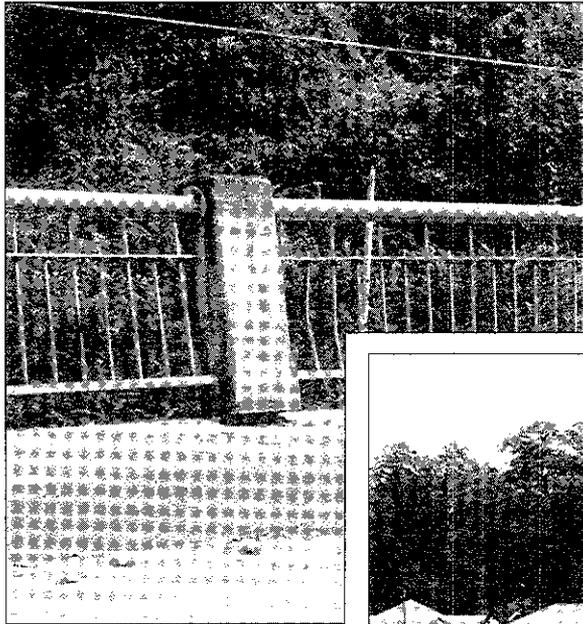


The barrier systems or bridge rails in the pictures above are across a large culvert and a small bridge. Both of these barriers are potential hazards. Both are too short to develop sufficient strength. The one on the left can be struck head on and would easily penetrate into the windshield of a car. The one on the right is constructed of miscellaneous leftover parts such as old railroad rail and has a “turned down” end that has the potential to vault a car into the trees or stream. This “bridge rail” could easily snag a wheel or launch a car.

It is desirable to replace these guardrail sections with crash worthy systems and terminals, or to extend the culvert ends far enough away from the travel way to eliminate the need for guardrails.

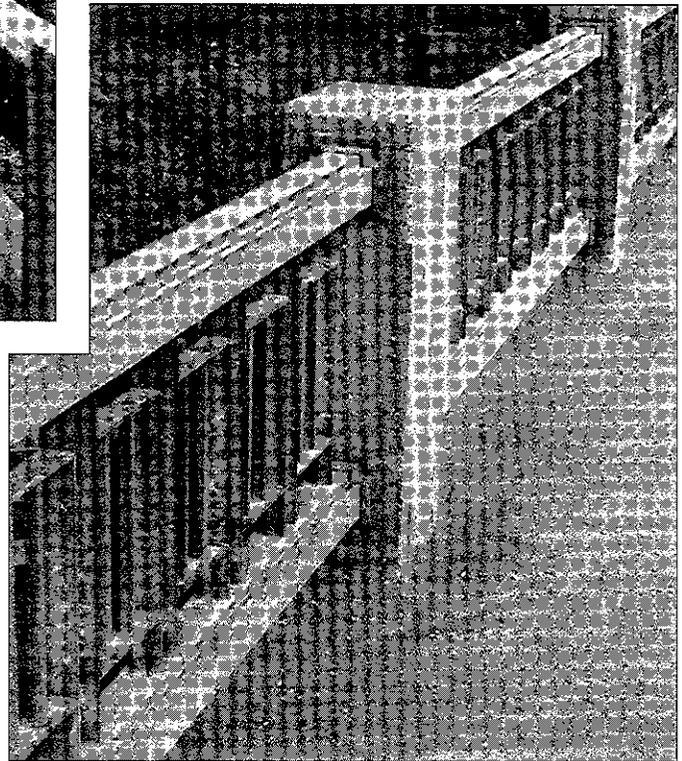
Recognizing Inadequate Bridge Rail **(Common Examples of Inadequate Bridge Rail)**

These pictures are examples of bridge rails on commonly used local roads and streets. These rails are functionally inadequate for highways with speed limits over 40 mph. The raised section of the bridge at the bottom face of the bridge rail is referred to as a "safety walk or sidewalk." This raised section can initiate the vaulting of a car over the bridge rail or cause the car to hit the bridge rail at a height where it might fail.



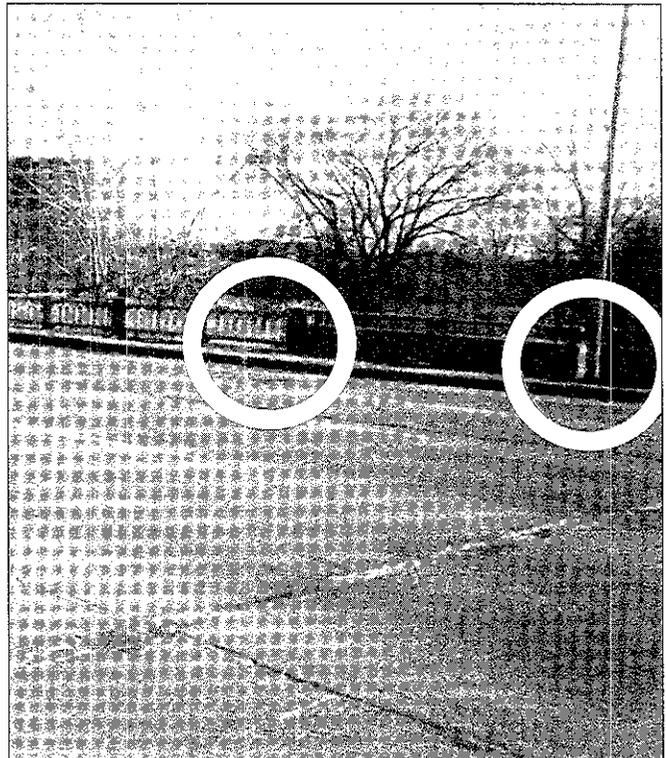
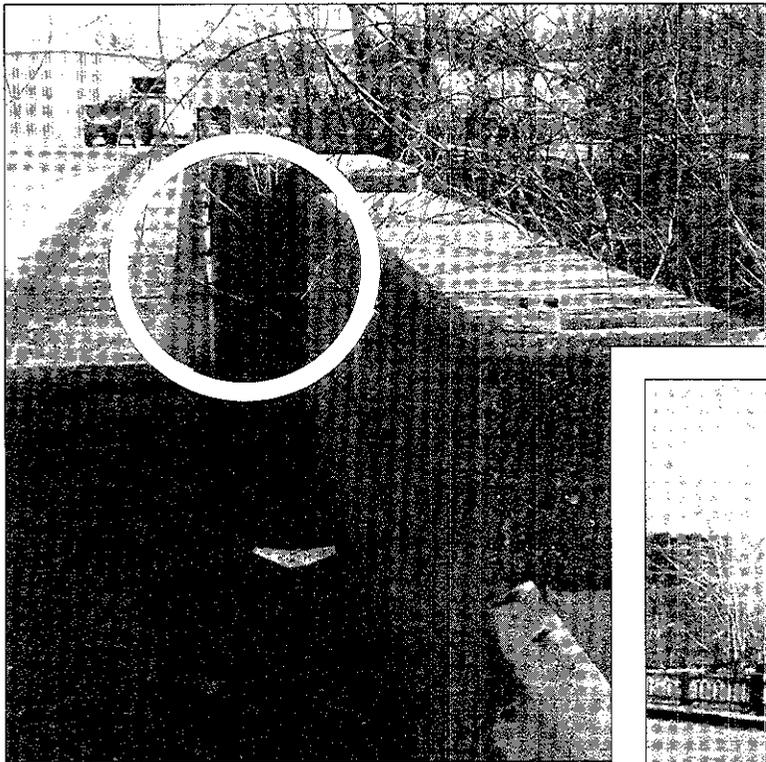
Recognizing Inadequate Bridge Rail **(Common Examples of Inadequate Bridge Rail)**

There are other types of older bridge rails that are inadequate because they have rigid features that could snag a car, causing it to stop rapidly, rotate sideways and be struck by another vehicle, or roll over.



Recognizing Inadequate Bridge Rail **(Common Examples of inadequate Bridge Rail)**

The following pictures provide examples of common bridge rails that are functionally inadequate because of the discontinuity in the bridge rail. Discontinuities are often the result of modifications during construction or some time later in the service life of the bridge that were built to accommodate some additional feature such as highway lighting. Like the snag points shown in the previous pictures, discontinuities can abruptly halt a car or cause it to go out of control.



Improving Inadequate Bridge Rails

One way to correct an inadequate bridge rail is to remove and reconstruct it to current standards. Unfortunately, the cost of replacing a substandard bridge rail is often high. This type of upgrading is generally planned when other bridge elements, such as the superstructure or bridge deck require major repair or upgrading. It may also be apparent that the existing bridge deck is not strong enough to provide an adequate base for the attachment of a standard bridge rail. Therefore, replacement of substandard bridge rails should be considered as part of any future bridge rehabilitation, reconstruction or replacement project.

Often a considerable improvement in the safety of the bridge rail can be made by a relatively easy safety upgrade. Safety upgrades should be considered only after it is determined that it is either economically or physically impractical to replace the existing bridge rail with a crash-worthy rail.

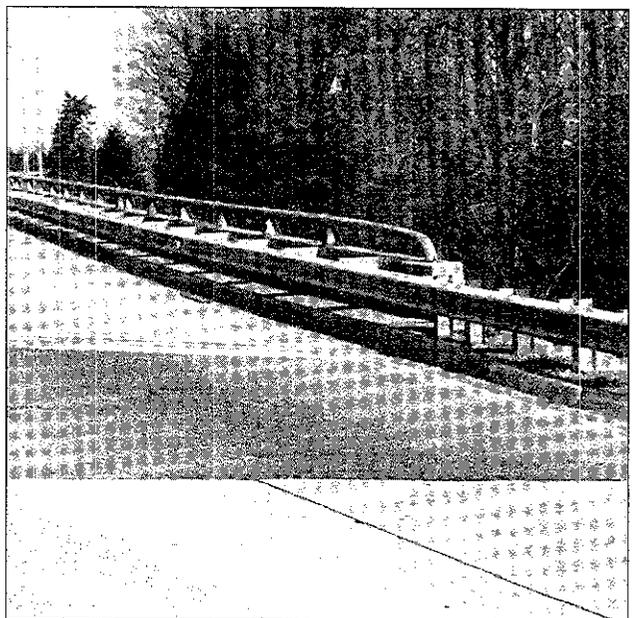
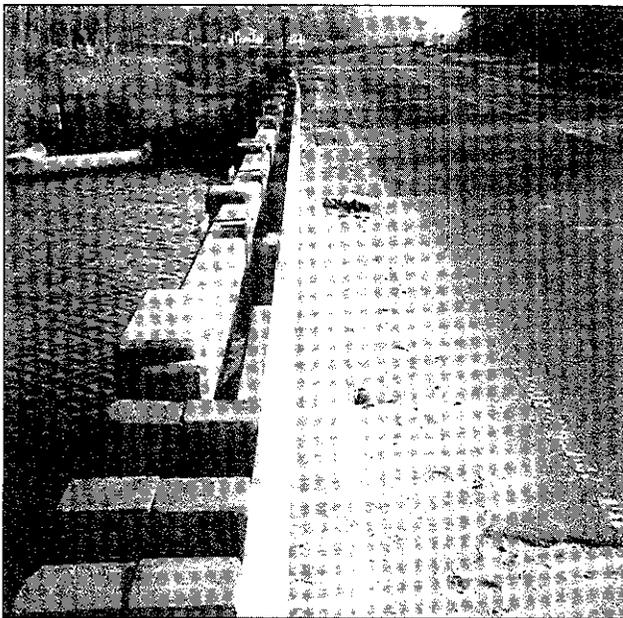
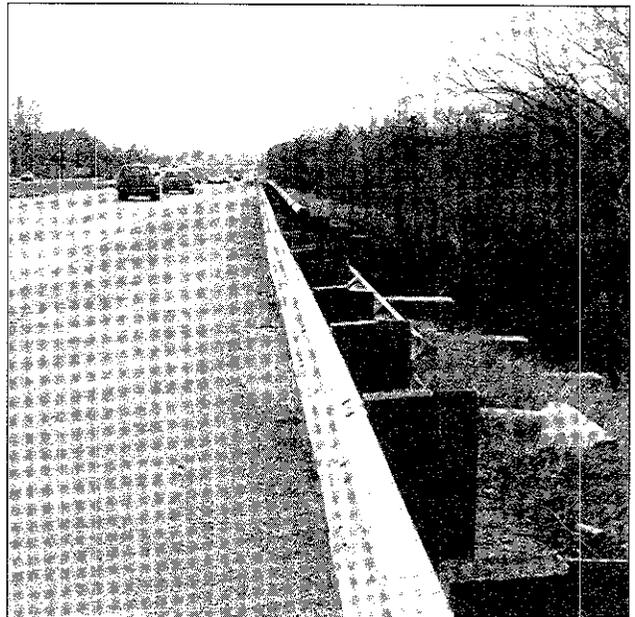
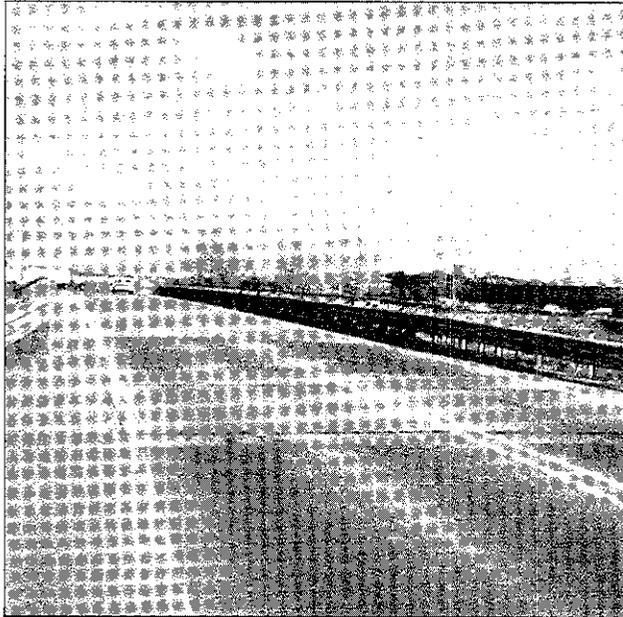
The most common and effective way to upgrade a substandard bridge rail is to add a continuous section of standard guardrail in front of and attached to the existing bridge rail. Both the standard sections of the W-Beam strong post system and the Thrie-Beam system can be used to improve a bridge rail that is substandard. This type of bridge improvement can be very cost effective when combined with other work that improves the functional adequacy of a bridge rail and the bridge guardrail approaches.

A continuous section of W-Beam or Thrie-Beam attached to the existing bridge rail, carried through the bridge approach areas, well anchored at both ends and with crash worthy terminals can be a very significant safety improvement. An example of such a temporary safety improvement is shown on page 20. This effort could have been further improved if the guardrail face was made flush with the bridge rail safety walk. This can often be done by using special wide block-outs as shown on the bottom right of page 20. When the "safety walk" is too wide, temporary intermediate posts on the safety walk may be constructed to bring the face of the guardrail flush with the edge of the safety walk.

Improving Inadequate Bridge Rails

The pictures below illustrate several common retrofits of guardrail components used to improve the structural and functional characteristics of a substandard bridge rail.

The retrofit on the lower left improves safety by providing a non-snagging continual rail. However, it still remains behind the existing “safety walk.” A better example of a safety upgrading is in the lower right picture where special wide blockouts were used to ensure the retrofitted rail was flush with the face of the “safety walk.”



Approach Guardrail

The approach guardrail is often the most important safety feature at a bridge or large culvert location. The approach guardrails frequently require a greater length to shield the motorist from the potential hazards of the site than the bridge rail. It is often located on or in a curved section of highway. Additionally, guardrail must be transitioned (stiffened) from its characteristic semi-flexible design to a rigid system before it is connected to the bridge rail. As discussed in the introduction, the approach guardrail must be both **structurally adequate** and **functionally adequate**.

A **Structurally Adequate** approach guardrail for high and low speed highways includes the following common systems:

- W-beam on wood posts with wood blockouts,
- W-beam on steel posts with wood blockouts, and
- Thrie beam on wood posts with wood blockouts.

These standard guardrail systems must be modified to include:

- An adequate connection to the bridge rail,
- A crash-worthy transition (stiffened) section between the standard semi-rigid approach guardrail and the rigid bridge, and
- A crash-worthy end terminal, when it can reasonably be expected that it can be hit by a car.

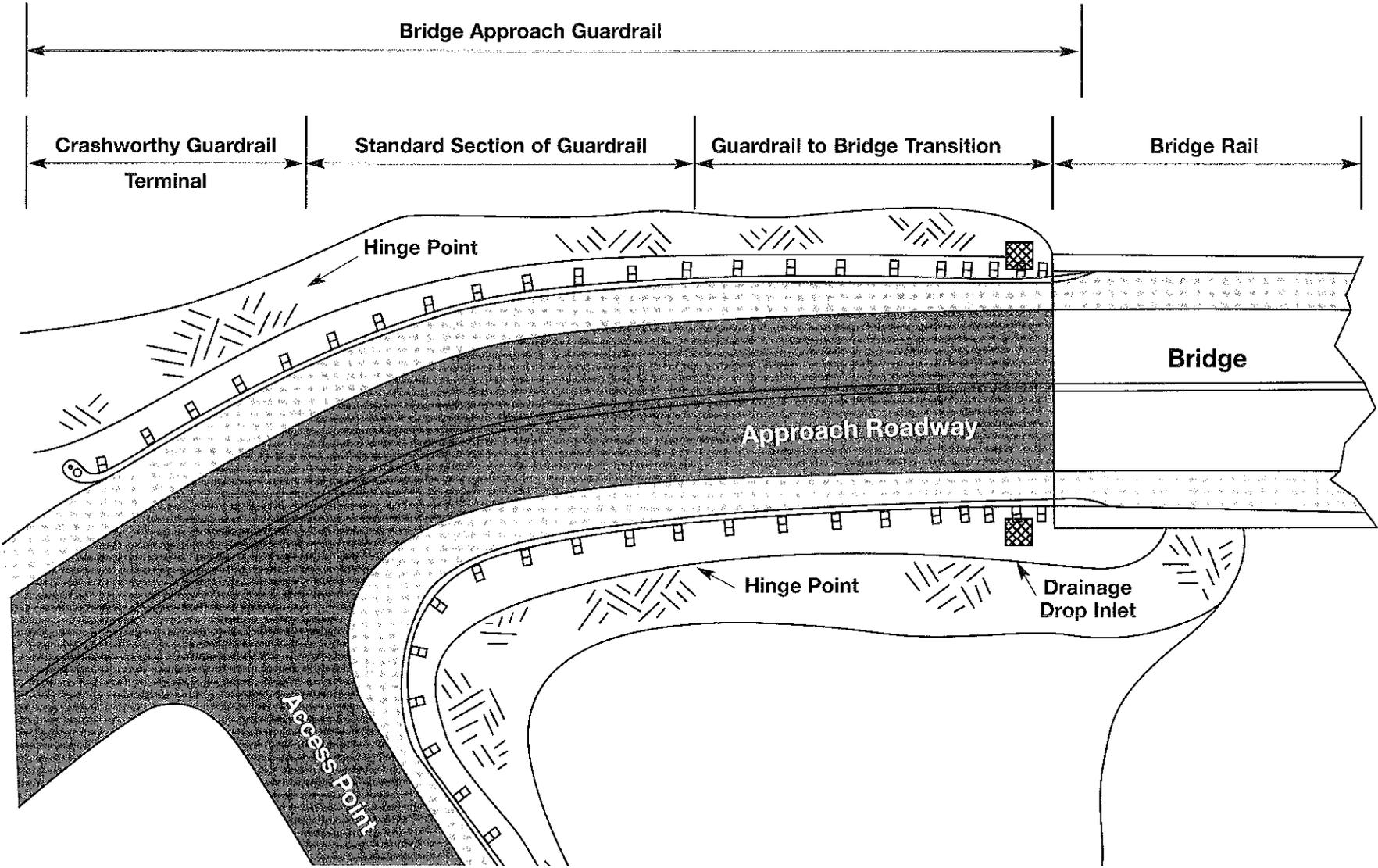
In addition, the approach guardrail must be **Functionally Adequate**. To be functionally adequate an approach guardrail must provide the following:

- Sufficient length to ensure that a car doesn't get around the approach guardrail and end up in the hazardous area.
- A design that redirects the impacting car along the bridge rail in a stable manner and 1) not into the opposing traffic or bridge rail or 2) not pocket and fold in on itself, causing a car to stop abruptly. [See Figure 6.]

Simply put, the approach guardrail should smoothly redirect an errant vehicle without snagging, abruptly decelerating, overturning, or penetrating the vehicle compartment.

Standard designs for guardrail systems may be found in state standard drawings or "A Guide to Standardized Highway Barrier Hardware." See references.

Bridge Approach

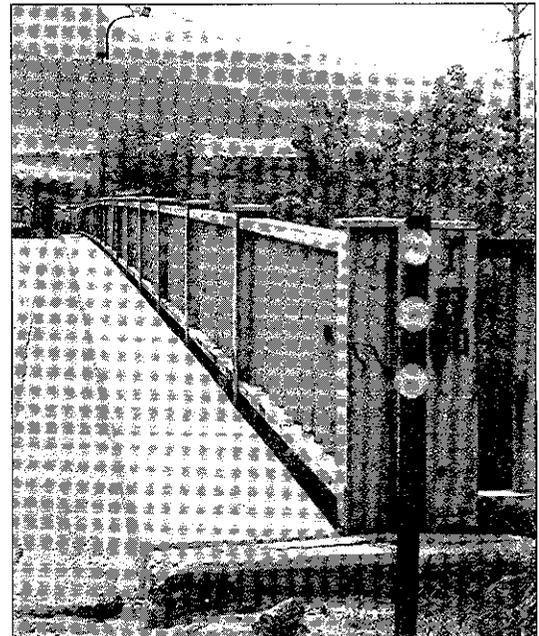
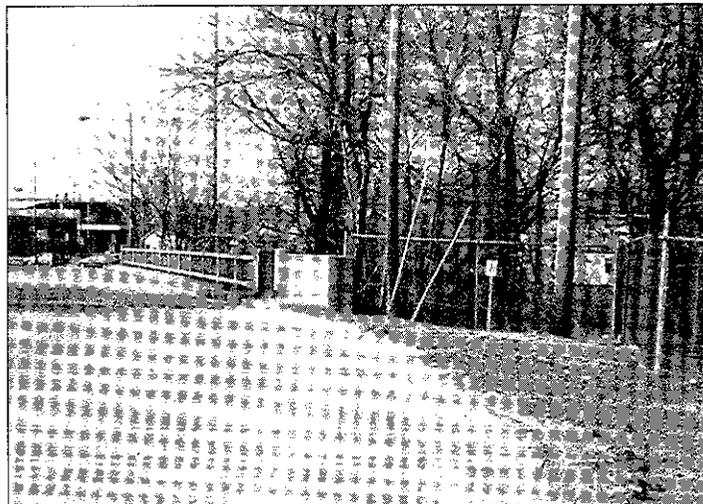
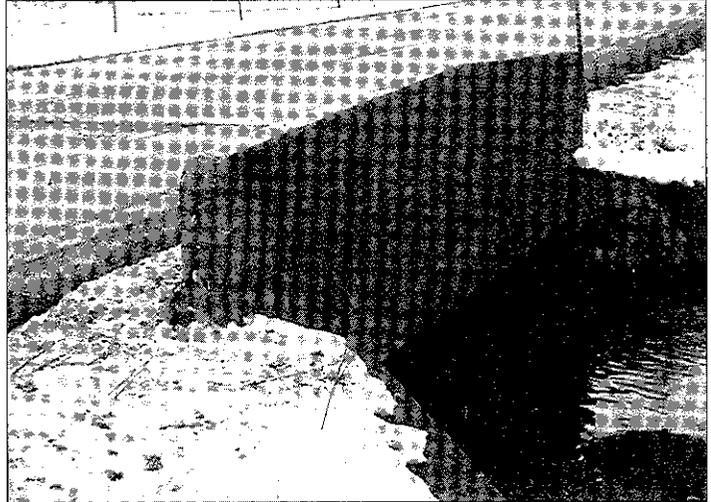
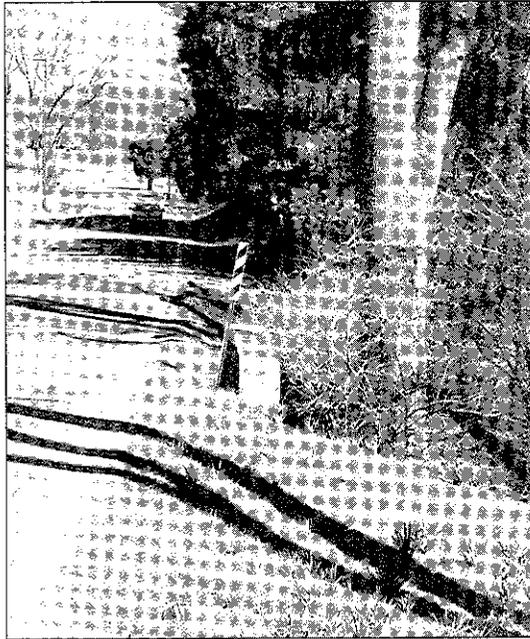


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Figure 5.

Approach Guardrail (Where is Approach Guardrail Needed?)

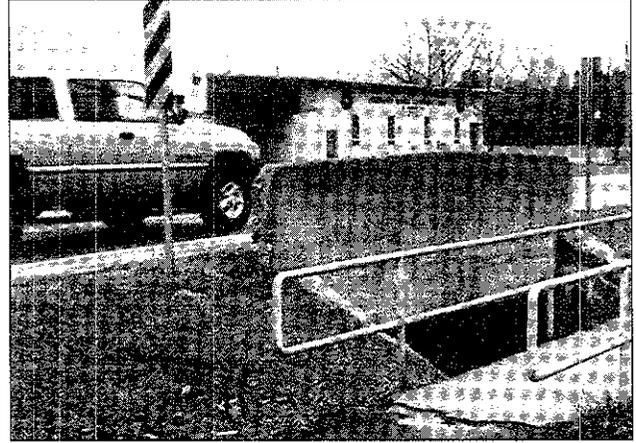
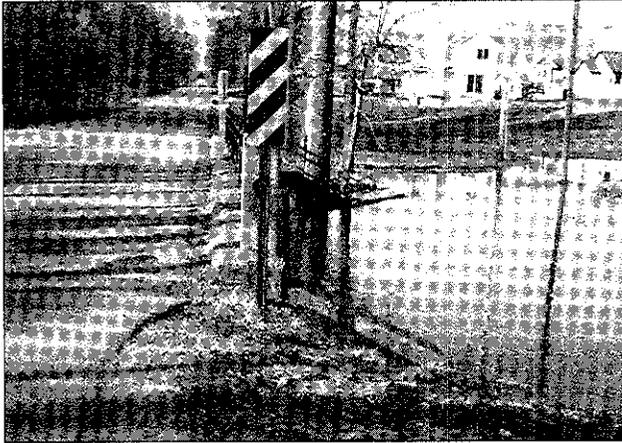
Rigid objects, such as bridge rails and culvert head walls, that are more than 4 inches above the surrounding ground have the potential to abruptly stop a car. These rigid objects can also snag the bottom parts of a car or initiate vaulting, either of which can cause the driver to lose control. Below are several examples of common bridge rails and culvert walls that require approach guardrails. These road features are extremely hazardous when not shielded with approach guardrail.



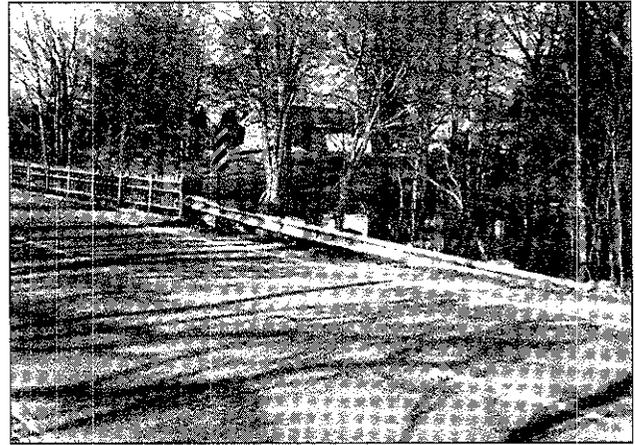
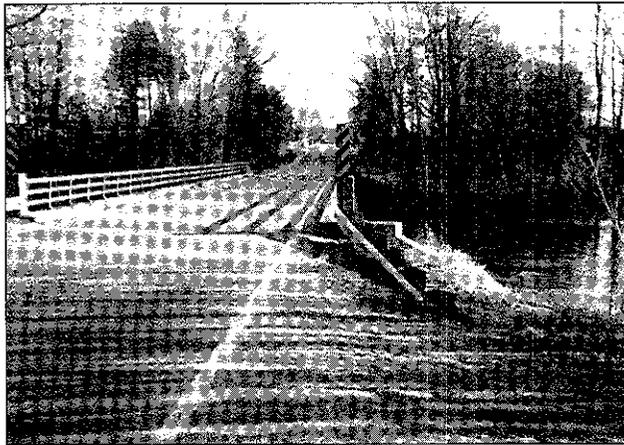
Each of these examples above are considered extremely hazardous because there is no approach guardrail on any of these rigid bridge rail terminals.

Approach Guardrail (How Much Guardrail is Needed at the Approach?)

Approach guardrail is also essential when the area directly behind the bridge rail is more hazardous than the other sections of the highway. As shown in the pictures below and those on the previous page, most bridges and large culverts are located across hazards and/or other potentially hazardous features.



An approach guardrail must be of sufficient length to prevent a car from going around it and into the hazardous area. The pictures below show approach guardrail that is not of sufficient length (referred to as “length of need” or the length of guardrail needed to shield the motorist from the potential hazardous areas).

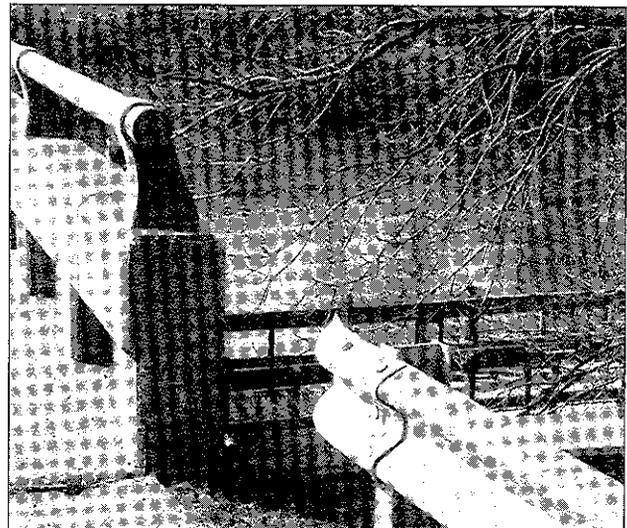
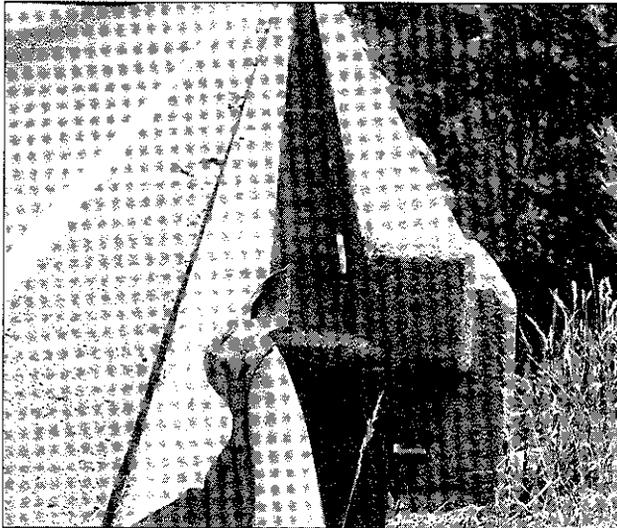


Note also the turned down ends of the guardrail present an additional potential vaulting hazard on higher-speed roads.

Approach Guardrail **(Strength and Continuity of Approach Guardrail)**

The approach guardrail should provide continuity in the transition of the barrier system from a semi-rigid guardrail system to the rigid bridge rail. Approach guardrails that are not crash worthy may create additional hazardous conditions. Common essential features of a crash worthy approach guardrail include: 1) adequate connection or anchorage of the guardrail system, 2) good transitions from the flexible guardrail system to the rigid bridge rail, and 3) crash worthy terminal ends.

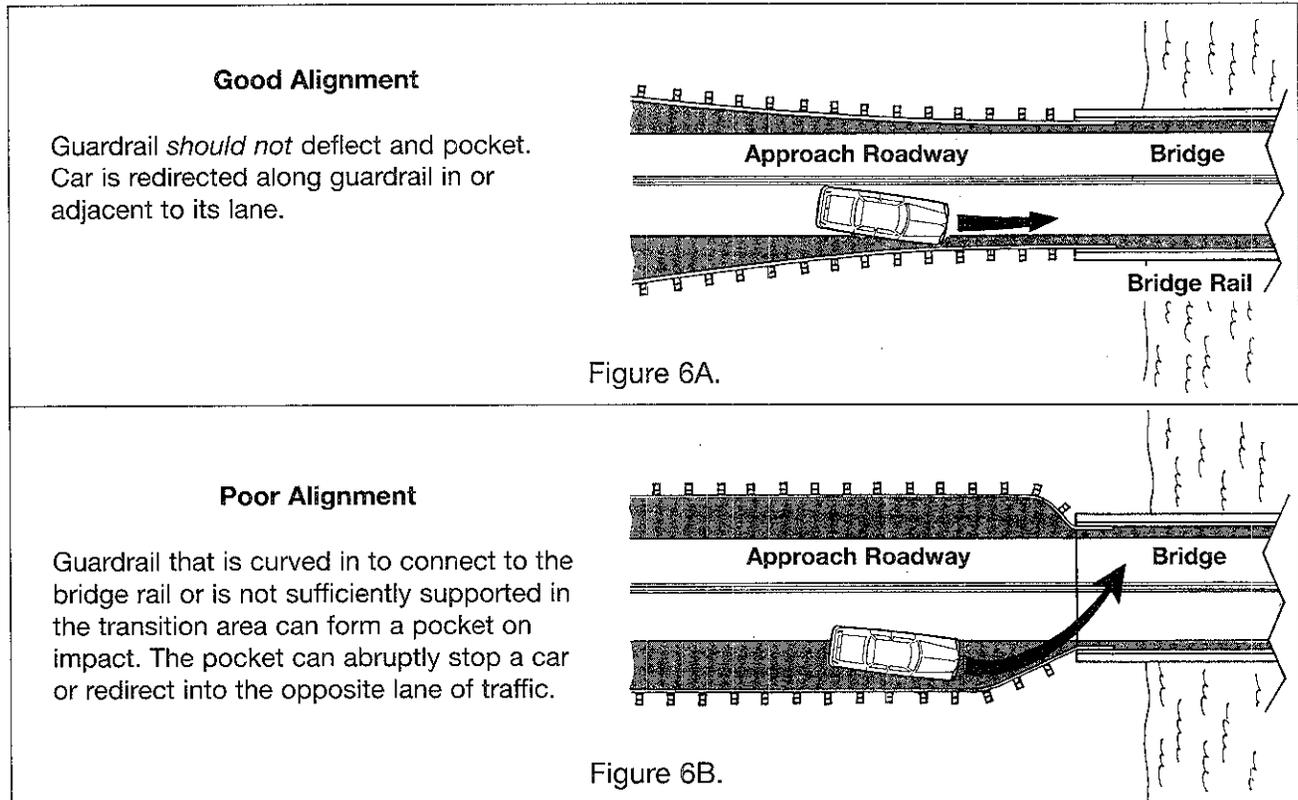
The guardrail must be adequately anchored to the bridge rail (this assumes the bridge rail has sufficient strength to provide for anchorage). The pictures below are examples of approach guardrail that is not attached to the bridge rail. This type of situation is hazardous because a car striking the approach guardrail can travel along the guardrail, pushing it back, and be directed into the fixed bridge rail or if the guardrail deflects enough into the hazard behind the bridge rail, in the situations below a deep river.



These pictures show examples of hazardous approach guardrail conditions because the guardrail is not connected to the bridge rail. Guardrail systems must be attached with the correct size and number of high strength bolts to insure they are adequately anchored.

Approach Guardrail

Adequately anchored guardrail systems can develop sufficient tension in a crash to safely redirect a car without separating from the bridge rail. The type and size of the appropriate bolts along with other standardized hardware guardrail components are specified in "A Guide to Standardized Highway Barrier Hardware" (see reference section).



Good Alignment and No Pocketing

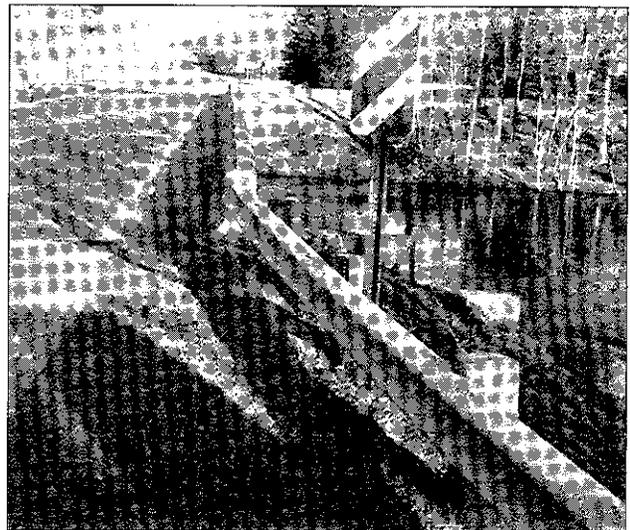
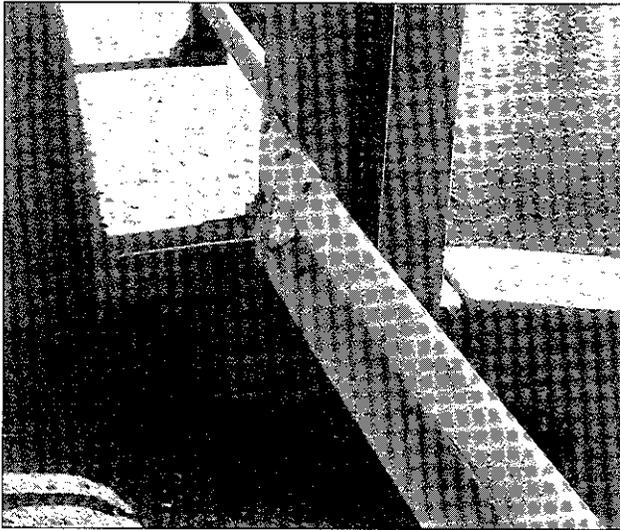
Approach guardrail that is parallel to the road or flared away at a rate of 1:15 or flatter and is sufficiently stiffened in the transition section should not pocket or deflect sufficiently to abruptly stop a car. Cars that strike parallel or correctly flared guardrail systems are redirected along the guardrail face, parallel to the travel lane (Figure 6A).

Poor alignment and/or weak transition sections

Approach guardrail that curves in to meet the bridge rail and/or is not stiffened in the transition section can deflect inward forming a pocket that traps the car and brings it to an abrupt halt. This can cause the guardrail to separate, or redirects the car into the opposing lane of traffic or the bridge rail on the other side of the roadway (Figure 6B).

Approach Guardrail (Adequate Alignment – No Pocketing)

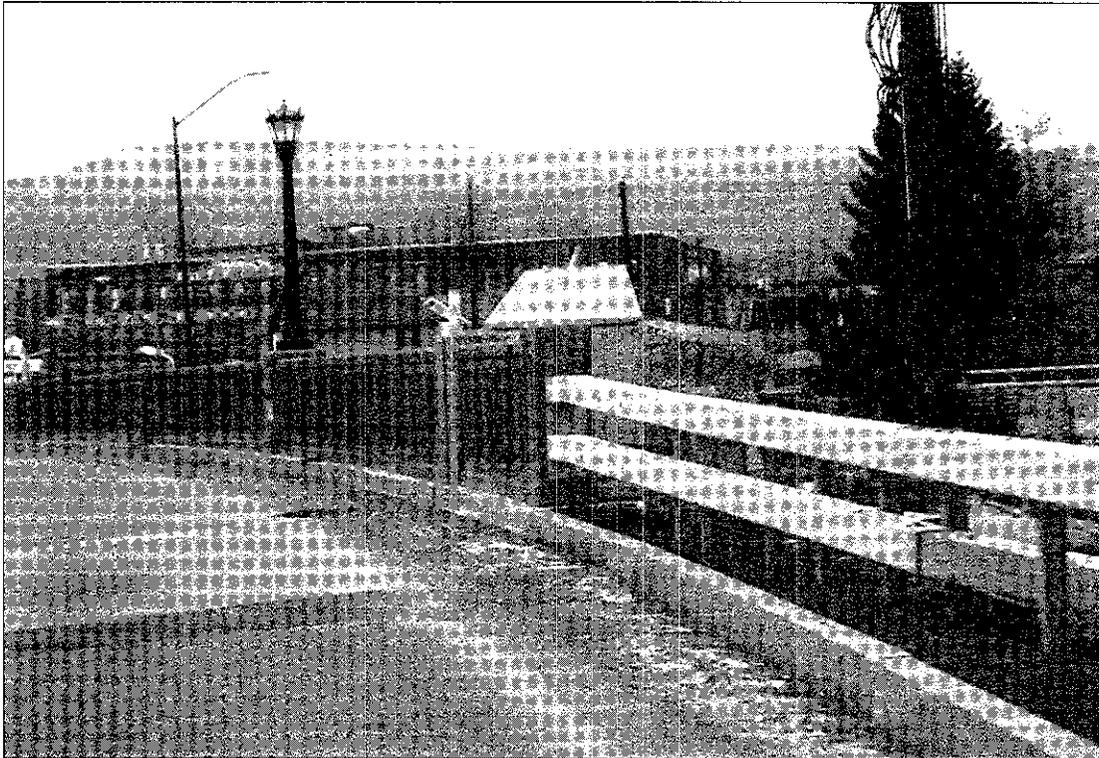
The approach guardrail must be **stiffened directly in front of the bridge rail**. This area is called the guardrail to bridge “transition” (see figure 5). In this area the guardrail must be stiffened so that if impacted it functions more like the rigid bridge rail to which it is connected than a standard section of guardrail that deflects on impact. When the guardrail is not stiffened (as shown in the pictures below) it can deflect and 1) direct the car into the end of the bridge rail, causing excessive deceleration, 2) cause the guardrail to form a type of pocket which can redirect the car across the bridge and directly into opposing traffic or the bridge rail on the other side, 3) place excessive forces on the guardrail beam and bolts causing them to fail and the car to be directed into or behind the bridge rail. The pictures below show two different approach guardrail installations that are not adequately anchored. They have not been stiffened sufficiently (note the lack of extra posts in the guardrail immediately in front of the bridge rail).



These pictures show examples of potentially hazardous approach guardrail systems. Neither of these approach guardrails is sufficiently strong enough to prevent it from deflecting, pocketing, or causing excessive force to rip or separate at the guardrail connections,

Approach Guardrail (No Snag Points)

In addition to the requirements to have approach guardrail systems anchored and stiffened to prevent deflection and pocketing, the approach guardrail should also prevent or eliminate the potential to snag or vault a car. The approach guardrail shown below, although adequately anchored to the bridge rail and stiffened to reduce deflection, has been attached behind the face of the bridge curb and bridge rail. **This approach guardrail is potentially hazardous** because it could snag or vault a car.



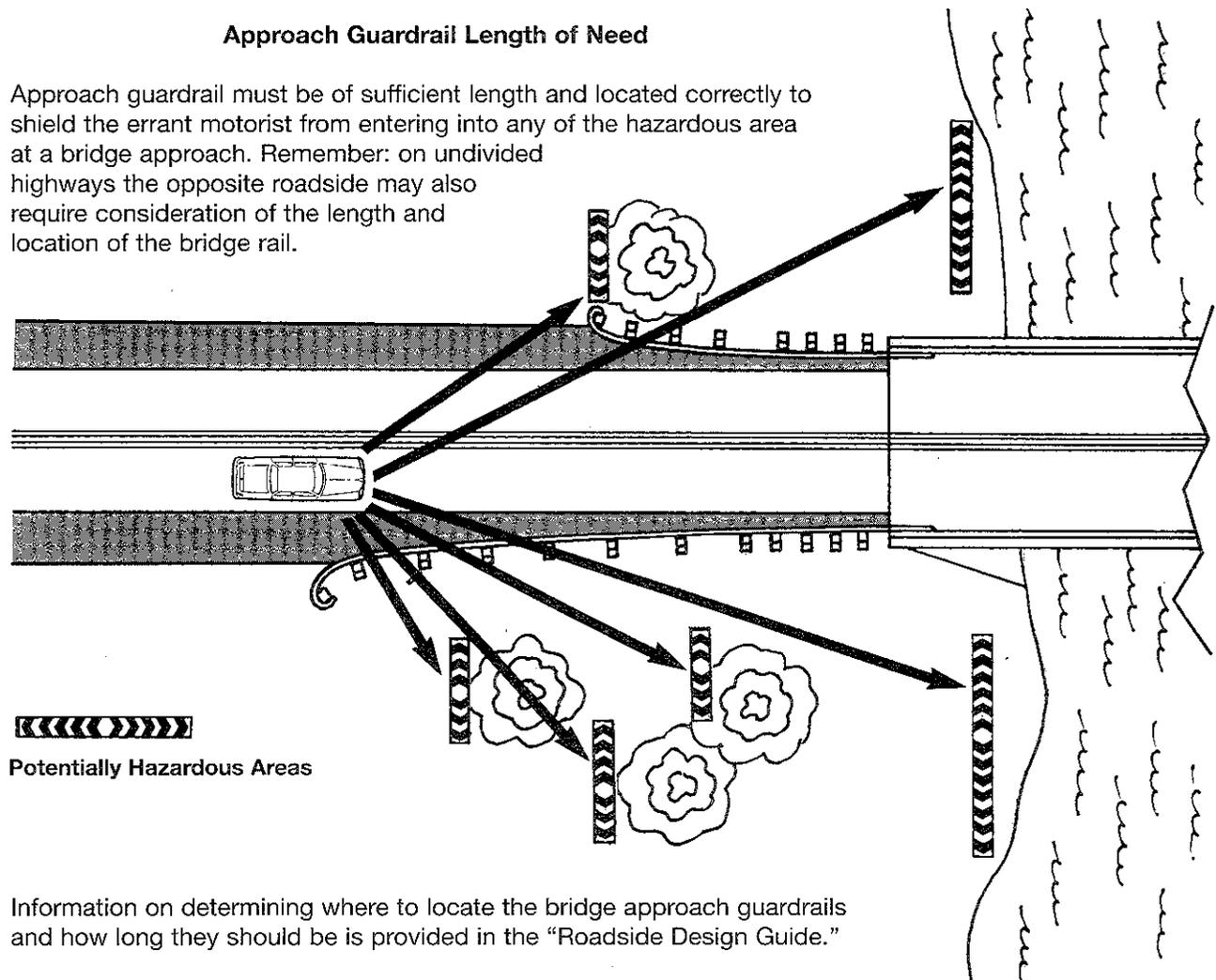
Approach Guardrail (Adequate lengths of approach guardrail)

The length of guardrail needed at each bridge can vary depending on the type of potentially hazardous features present, the grading of the bridge approach, other features on the approach road side, and where the guardrail is located (see figure 7). The "Roadside Design Guide" provides information on determining the "where to" locate and "what" length of guardrail to use in each situation. It is important to remember that even guardrails on the opposite side of the bridge should be checked to insure they provide adequate protection for a car crossing over the roadway and leaving the roadway, particularly when the roadway curved.

Common potential hazards in the area of a bridge approach include; deep streams or rivers, trees, steep side slopes, and roadway drainage features.

Approach Guardrail Length of Need

Approach guardrail must be of sufficient length and located correctly to shield the errant motorist from entering into any of the hazardous area at a bridge approach. Remember: on undivided highways the opposite roadside may also require consideration of the length and location of the bridge rail.

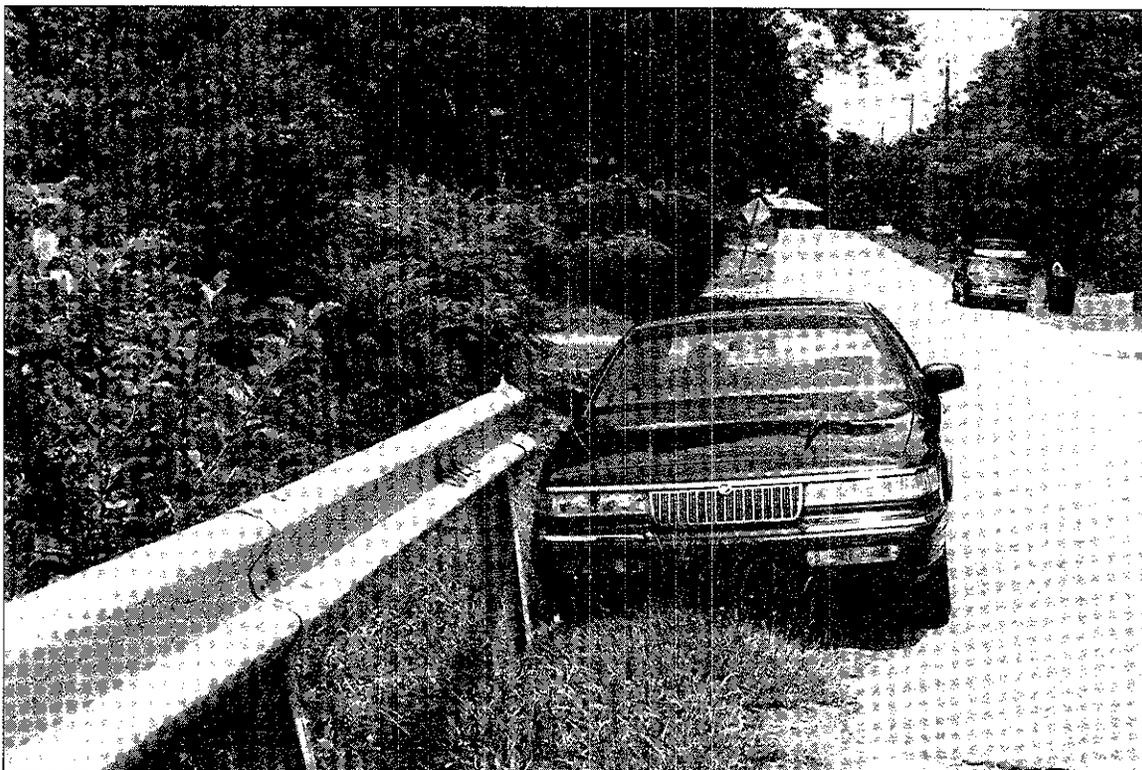


Information on determining where to locate the bridge approach guardrails and how long they should be is provided in the "Roadside Design Guide."

Figure 7.

Approach Guardrail (Crash worthy Terminals)

Approach guardrail for bridges should be ended in a safe manner. The unprotected end of a guardrail can be as hazardous as the unprotected end of a bridge rail because it can 1) abruptly stop a car, 2) cause the car to become unstable and overturn, 3) cause the car to spin out in opposing traffic, or 4) penetrate the vehicle compartment, causing serious injuries. The picture below demonstrates how easy it would be for this noncrashworthy end of guardrail to penetrate into the passenger compartment of a car.



There are two main ways to end a guardrail safely. The first is to flare the guardrail back at an appropriate rate away from the roadway and end the guardrail far enough away from the travel lane so that it is unlikely to be hit in a crash. This is usually referred to as ending the guardrail beyond the clear zone for a particular location. Even when a guardrail is ended beyond the clear zone, it should not be left as a blunt end (the guardrail pictured above is a blunt end). In these cases it is desirable to still use a crash worthy terminal or turn the end back into an existing cut slope.

The second way is to terminate the guardrail with a crash-worthy terminal.

There are several types of different crash worthy terminals available, including several excellent commercial terminals. Information on these terminals and how they are used is provided in the “Roadside Design Guide” (see the reference section for information on this publication).

Bridges

Posting Bridges for Maximum Loads

Bridges carrying traffic on public roads are typically inspected every 2 years as required by the National Bridge Inspection Standards. As part of the inspection program, each bridge is rated for its load capacity. If a bridge's capacity is not at least equal to the State's maximum legal loads, it is required to be load posted. Bridges which rate at less than a 3 ton load capacity must be closed. Bridge owners will receive reports from the bridge inspection team that contain information related to damaged or deteriorated members and the need to load post or close a bridge.

Load posting signs, especially in rural areas, are often vandalized or removed. Ignoring this problem can expose the traveling public to unsafe conditions, and the bridge owner to tort liability.

A reasonable program of periodic monitoring and replacement should go a long way toward protecting the public at a reasonable cost.

Pedestrian and Bicycle Traffic

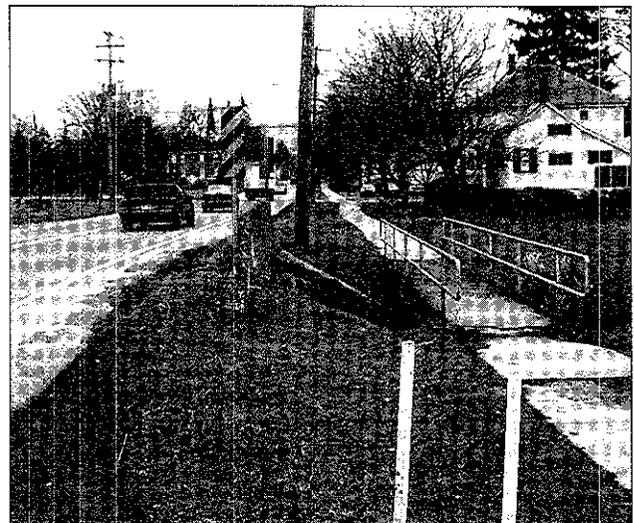
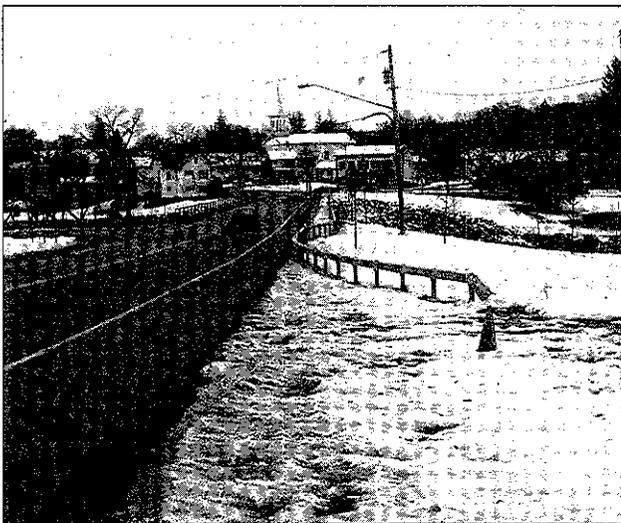
When considering the selection of an approach guardrail system or a terminal to be used in connection with a bridge rail system, it is important to consider the overall impact of a design selection on all users of the bridge. Pedestrian access must be maintained and should be enhanced on the structure and its approaches, if possible.

A major bridge may well be the only available crossing point for pedestrians - in which case, they will be forced to use the facility in an unsafe manner, if that is all that is made available for them. Keep in mind that a bridge project represents what may be the only opportunity to provide or upgrade pedestrian facilities on a bridge for a significant time period. As such, it is essential to provide the safest accommodation for pedestrians and bicyclists that can reasonably be made.

The impact of guardrail and terminal placement on pedestrian access should be evaluated during the design stage. Care should be taken to provide a clear, safe, and uninterrupted path for pedestrians as they travel the approaches and cross the bridge.

The photo on the left illustrates a situation where an improperly located flare in a box beam guardrail will force pedestrians out into the pavement as they approach the bridge. The needed flare for this guardrail system could be provided without channeling the pedestrian out into the roadway. A guardrail approach with flare must be constructed for the specific deflection distance required by the barrier system being used.

The photo on the right shows another installation, wherein a railing has been provided for users of the sidewalk. Note, however, that the culvert head wall is a tall blunt object dangerously close to the roadway. In this instance, the sidewalk is probably far enough from the edge of the roadway to allow a proper terminal and transition installation without disrupting pedestrian travel on the sidewalk.



Safer Roadway Approaches at Bridges

One of the most important characteristics of safer roadways is the absence of confusing or hazardous roadway and roadside features that can surprise a driver. An example of this is a very sharp curve within a series of smooth curves or a hidden access points. These features may not be confusing to all drivers but occasionally these type situations confuse or surprise unfamiliar drivers. When drivers are surprised and/or required to take some abrupt action, there is a greater chance a wrong decision may be made. Failure to make the correct decision in a timely manner or over react to the situation can cause a crash.

To avoid surprising the driver, provide him or her with a timely advanced warning about any changes in the roadway conditions. One of the best ways to provide advanced information is to let drivers see the existing conditions well in advance of any action or decision that needs to be made. This is generally done by providing good sight distance. As an example, a driver is more likely to be surprised by a vehicle pulling onto the highway from a hidden intersection than one where the vehicle can be seen approaching the intersection. Of course features such as sharp curves are not easy for a driver to identify. In these cases warning signs or other informational methods can be employed to provide the necessary information to the driver.

Many local roadways run parallel to rivers or streams before crossing them. One of the common characteristics of older bridges was to construct the bridge perpendicular to the river or stream to minimize the length of the bridge. This often results in sharp highway curves at the bridge approaches. Another common characteristic found on some local bridges is the intersection with other local roads at the bridge approach. Either of these features could surprise a driver whose field of vision is blocked by vegetation growth.

Safer Roadway Approaches at Bridges (Sight Distance)

Good sight distance at the bridge approaches is one of the most important elements of safety. Removing and maintaining vegetation that restricts sight distance is often one of the most cost-effective ways to enhance highway safety. It is important to ensure that at a minimum, there is adequate sight distance both of the bridge approach and all regulatory or warning signs in the bridge approach area.

Seeing the bridge approach is particularly important when; 1) there are access points at or adjacent to the bridge, 2) it is a narrow bridge—the bridge width is less than the approach roadway width (see figure 1), 3) there is the possibility that pedestrians will be on the bridge or crossing the approach roadway and/or 4) the roadway curves sharply at the bridge approach.

Seeing warning and regulatory signs or traffic control signals, such as curve warning signs, ice warning signs, or traffic signals in a timely manner is also very important.

Good sight distance allows the driver to prepare for any change and take any appropriate actions in a timely manner.

Sight distance should always be checked in the summer when trees and crops in adjacent fields are at their full growth. As shown in the picture below, critical information can be obscured by vegetation.



Safer Roadway Approaches at Bridges (Appropriate Signs, Markings and Delineation)

Signs, pavement markings, and delineation are especially important in the area of the bridge approach. Often these devices provide the driver with essential decision making information at night, during inclement weather, and in areas where adequate sight distance is not available. Information on appropriate signing, pavement marking, and delineation that should be used, including the type, size, and location of these devices is provided in the “Manual on Uniform Traffic Control Devices”(MUTCD).

Signs may also be used to help improve or mitigate the potential adverse affects of substandard bridge, bridge rail, or bridge approach design features. The “Object Marker” panel should be used at/on potentially hazardous fixed objects in the bridge approach area. As shown in the pictures below, both bridge abutments are rigid fixed objects that tend to blend in with the surrounding environment. Marking the potential hazard with a retro reflective object marker panel can help a driver avoid hitting the end of this bridge rail.

The use of warning signs is not a substitute for more positive corrective actions, but signs can be used as an immediate or temporary improvement until a safety upgrading is made.



The photo at the left is an example of a bridge rail/culvert head wall that a driver might not see at night or in rainy weather. The driver could hit it, or when becoming aware of it, abruptly turn into the other lane. The photo at the right demonstrates how effective object markers can be in warning a driver of the potential hazard.

Pavement marking, both center line and edge line markings, help the driver understand where it is safe to travel. Pavement markings are particularly important on narrow bridges where the shoulder area is reduced because drivers may tend to move away from the approach guardrail or the bridge rail and inadvertently encroach on the opposing traffic lane. While pavement markings are important to the drivers, they may only be seen in the immediate area because bridge/roadway geometric and the bridge rail that may block the view of the driver. When the driver's view is blocked, other driver guidance, such as delineator, should be used to supplement the pavement markings.

Roadway delineators are important in the area of the approach roadway and on the bridge itself when the approach and/or the bridge are on a curved alignment, when the alignment and bridge rail block the drivers view of the pavement markings, at narrow bridges, or where the travel path could be confused. Supplemental delineation of the guardrail and bridge rail may also be desirable. Both can help a driver safely negotiate the travel path at night or during implement weather. Information on pavement markings and delineation is available in the MUTCD.

Examples of Good Safety Improvements

Many good examples of safety improvements exist. They include retrofitted guardrail systems to improve the strength of weak existing bridge rails; better alignment in the bridge approach; stiffening of guardrail transition sections with more, and in some cases, larger posts; stronger guardrail to bridge connections; and better signage, delineation and pavement markings.

Photos of these improvements were not included because experience has shown that occasionally these "type" improvements are copied inappropriately. When considering or designing a safety improvement, an appropriately experienced highway safety engineer, bridge engineer, or safety specialist should be consulted.

References

1. The "Roadside Design Guide," American Association of State Highway and Transportation Officials.
2. "Crash Testing and Evaluation of Retrofit Bridge Railings and Transitions" Publication No. FHWA-RD-96-032, January 1997.
3. Transportation Research Record No. 1367 "Development and Evaluation of Roadside Safety Features," 1992.
4. "A Guide to Standardized Highway Barrier Hardware," An AASHTO-AGC-ARTBA Joint Committee, Task Force 13 Report. This document is available from the American Association of State Highway and Transportation Officials (AASHTO).
5. "Manual on Uniform Traffic Control Devices," Federal Highway Administration, 1988.