

Roadway Safety and Guardrail

Recent studies show that careful roadside design can improve highway safety significantly. Ten to 15 percent of all accidents involve a single vehicle running off the road and hitting a roadside object. Of the fatal accidents which involved hitting fixed objects, 35 percent occurred within ten feet of the pavement edge and 70 percent within 20 feet. Roadside characteristics such as sharp curves combined with hazardous ditches, trees and other objects are involved in 83 percent of fatal crashes into fixed objects on local roads.

The most effective safety measure is an unobstructed, flat roadside. When that is not possible, properly installed barriers such as guardrail or crash cushions will help. This bulletin describes general roadside safety and discusses proper guardrail use. If you choose to install guardrail, you should follow the detailed instructions in the *Guide for Selecting, Locating and Designing Traffic Barriers (Guide)*, produced by the American Association of State Highway and Transportation Officials, and the Wisconsin Department of Transportation *Facilities Development Manual*.

The clear roadside concept

The safest roadside is clear and flat—free of obstructions and steep slopes. Since such conditions are rare, you must decide how to protect errant vehicles from trees, utility poles, embankments, bridge abutments, deep ditches, and other roadside hazards. First, attempt to remove or relocate the hazard. If that cannot be done, a safety barrier like a guardrail may be necessary. However, since the barrier is itself an obstruction, be sure that it is less of a hazard than the object it is protecting.

Since 70 percent of the fatal crashes involving fixed objects occur within 20 feet of the pavement edge, it is logical to assume that the first 20 feet of roadside should be as clear of hazards as practical. However, traffic

volume, traffic speed and roadside conditions affect the size of clear zone needed for each road. In general, clear zones should be wider when there is more traffic on the road and when speeds are higher. Clear zones also should be wider on the outside of curves and should increase as side slopes become steeper. The *Guide* gives specific clear zone recommendations.

Specific roadside hazards

Hazardous objects commonly found along roadsides include trees, drainage ditches, drainage pipe ends, stored equipment and materials, mailboxes, driveways and crossroads, bridges, and signs.

Trees A tree more than four to six inches in diameter is considered a fixed object. Trees in the clear zone are probably the most frequently encountered hazard. Small trees can grow into large ones in only a few years. Therefore, all trees in the clear zone should be removed when they are identified.

Drainage ditches Ditches along the roadside can be a significant hazard if a vehicle cannot easily travel down and up its slopes. In general if the side slopes are at a pitch of 3:1 or flatter no guardrail is needed. The *Guide* gives proper slope and cross-section designs for ditches.

Drainage pipe ends The end of a drainage pipe in a clear zone can be a serious hazard. The pipe end and its headwall should be shaped at the same angle as the side slope. You can also cover ends of pipes over 30 inches in diameter with grates. Headwalls or other obstacles should not extend more than four inches above ground.

Equipment and material storage The clear zone applies to temporary objects as well as fixed ones. Equipment and material should preferably be stored more than 20 feet away from the driving lane.

Mailboxes Mailboxes with heavy supports, and multiple mailboxes supported by large planks are serious hazards.



Boxes should be mounted on supports designed to break away on impact with strengths similar to those given below for signposts. Make sure boxes are located far enough off the roadway to allow delivery vehicles to stop safely. The AASHTO *Guide for Erecting Mailboxes on Highways* is a good reference. The local Postmaster should have a copy and can be helpful in removing hazardous mailboxes.

Driveways and crossroads Driveways and crossroads which intersect a main roadway are another common hazard. The slope of the driveway embankment and the headwall of any necessary culvert should be as flat as possible, preferably 10:1. Decorative headwalls can be a hazard. These can be controlled in new construction by specifications for safe headwalls.

Bridges Bridge abutments and ends of railings are severe hazards. New bridges with average daily traffic greater than 300 vehicles will have approach guardrails. Where guardrails are to be added or upgraded on an existing structure, bridges with high traffic volumes, narrow widths or a history of accidents should be done first. Other factors warranting guardrail include steep dropoffs, deep water, and bridge ends on the outside of curves. Proper anchorage to the bridge rail is necessary. In all cases, Type 3 object markers are recommended to delineate bridge ends.

Signs Signs and their supports are necessary to the efficient and safe flow of traffic. They may also be hazardous to errant vehicles. Use breakaway supports which yield on impact whenever possible; otherwise shield supports with guardrail. Tests show that the following sign supports break under vehicle impact: pine four-by-four inch or four-by-six inch posts, steel channel section U-posts less than three pounds per foot, and steel posts with a two inch inside diameter. These types of supports are considered breakaway.

Treating hazards within the clear zone

Ideally the clear zone should be free of all hazardous objects. To accomplish this, remove or relocate the objects. Trees, for example, are commonly removed, while utility poles can often be relocated. When objects cannot be cleared away because they are needed, or because of physical or economic reasons, they should be designed to yield on impact. Sign and mailbox supports are typical examples. Objects like overhead sign supports and bridge piers which cannot be made breakaway should be shielded by such crash cushions as

collapsible sand-filled or water-filled barrels, or protected by guardrails. Where shields are not practical, use appropriate warning signs. Removal and relocation are preferable. Use protection and warning only as a last resort.

Barriers

Crash cushions and guardrail are commonly used shielding techniques. Crash cushions are most often located on higher volume roads where guardrail cannot be used effectively, or in high accident locations. Strong post cable barriers are now unacceptable, although they are still frequently found along Wisconsin's rural and low volume roads. The most common acceptable barrier used in the state is the galvanized steel W-shaped guardrail on wood posts.

Barriers can be flexible, semi-flexible or rigid, depending on how far they yield on impact before stopping a vehicle (deflection). Cable systems may deflect as much as 12 feet. This is a flexible system. W-beams on wood posts six feet three inches apart (*strong post systems*) are semi-flexible. These will deflect up to four feet on impact. Special safety-shaped concrete barriers, commonly found in medians of high-speed, high-volume freeways, will not deflect and are called rigid systems. Bridge railings are also rigid systems. The following discussions of guardrail refer to Wisconsin's most commonly used acceptable guardrail system on local roads—W-beam on wood post system.

It is important to remember that the guardrail itself is a potential hazard. It is usually a larger target than the object it is shielding, and it is located close to traffic. Therefore, make every effort first to remove hazards that are in the clear zone. Those that can't be removed should be made less hazardous (like replacing heavy mailbox or sign posts with breakaway posts for example). If neither of these alternatives is practical, then consider shielding the hazard with a guardrail.

If hit under expected conditions, a guardrail should:

- Prevent an out-of-control vehicle from impacting the hazard being shielded.
- Redirect the vehicle without allowing it to penetrate the barrier, vault over it, or snag on it, and without creating an undue hazard to other traffic.
- Accomplish its shielding and redirecting functions without causing serious injury to the vehicle's occupants.



Typical Use of Transition, Standard and End Section of Guardrail

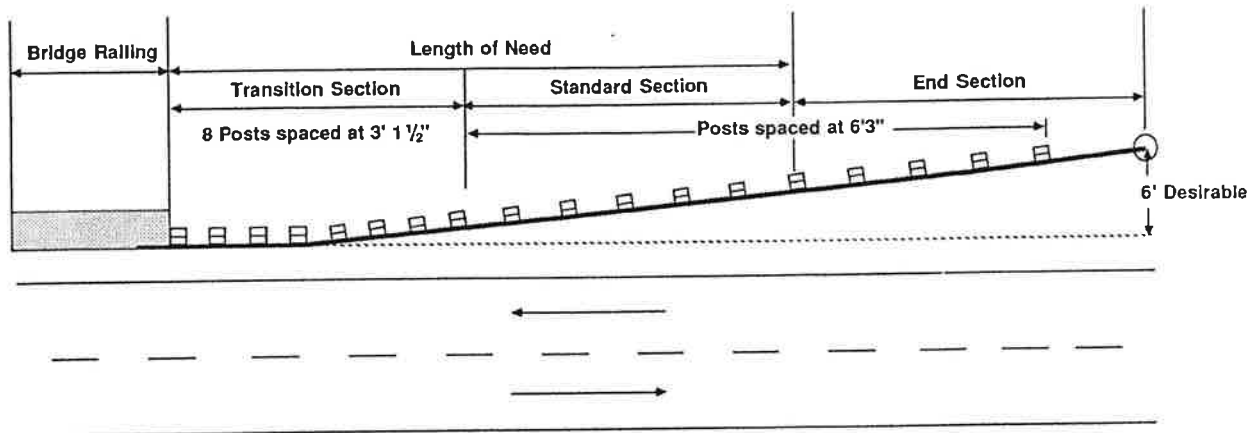


Figure 1

Guardrail system components

A W-beam strong-post guardrail system is designed to absorb the energy of an out-of-control vehicle in three ways. The beam transfers the energy along the length of the guardrail; the individual beam section bends; and the posts carry the energy into the supporting soil, often breaking under the impact as well. The crushing of the vehicle body also absorbs energy. The guardrail system has three major components: the standard section, the end section, and the transition section (figure 1).

The **standard section** is usually a 12 foot 6 inch beam supported at 6 foot 3 inch intervals by three posts. Standard sections are generally located between an end section and a transition section or between two end sections.

The **end section** ends the guardrail strongly and safely. Strength is provided by anchoring its end to the ground or to a backslope. Safety is ensured by installing a crashworthy end which will minimize injuries and property damage when hit head-on. If a guardrail simply stops without a proper end section the protruding beam end could impale a vehicle which crashes into it. It also may not be strong enough to protect the vehicle from the hazard it is shielding. Furthermore, a strong, anchored end is critical to the strength of the entire length of guardrail.

The **flared back and anchored down end** (figure 2) is used commonly in Wisconsin. Two other types of crashworthy ends are the breakaway cable terminal and the turned down and anchored end. It is very important to pay attention to details of construction and maintenance if the end section is to perform its function.

The **transition section** is intended to make the transition between guardrail types with different amounts of stiffness or deflection. For example, when a guardrail leads to a bridge railing, a transition section is needed between the semi-flexible standard section and the rigid, concrete bridge railing which has virtually no deflection, to direct an errant vehicle smoothly back to the road. The transition section of a W-beam guardrail usually has posts spaced about three feet apart.

When the guardrail is fastened to a bridge railing or some other rigid object, the connection should be strong enough to anchor it firmly. For a strong connection, drill through the concrete and use full strength fasteners. This is one of the most important features of transitioning a semi-flexible guardrail into a rigid barrier or fixed object. A simple strap which pops open on impact, will allow the out-of-control vehicle to crash into the rigid barrier end instead of redirecting it onto the roadway. Specific fastening details for transition sections are available from the Transportation Information Center or the Wisconsin Department of Transportation.



Guardrail performance factors

Guardrail system performance is affected by system strength, height, length, end sections, offsets, post spacing and embedment, beam splicing, and transition section length and strength. It may also be affected by conditions around the guardrail. Figure 3 illustrates details of these performance factors.

System strength Guardrails perform as a system. A single inadequate part may defeat the whole system. Strong, properly installed connections ensure strength. Missing bolts and hardware can cause a system failure.

Proper guardrail height To function properly the top of the guardrail must be 27 inches above the adjacent ground (for W-beam types). A tolerance of plus or minus three inches is acceptable. Vehicles can snag on a

guardrail that is too high, while they may ride up and over guardrails that are too low.

Adequate length The proper length of a guardrail is specific to the site and can be influenced by vehicle speeds, location and size of the hazard, side slopes, roadway alignment, and other conditions. The guardrail must be both long enough, and properly sited so a vehicle that leaves the road before the guardrail begins cannot get around the end section and enter the hazardous area.

End sections Untreated, unprotected or blunt end sections can penetrate the front of vehicles during head-on impacts, possibly causing severe injury to occupants. The end also must be securely anchored in order to develop the strength of the rail system. Figure 2 shows typical end section details.

Guardrail Terminal

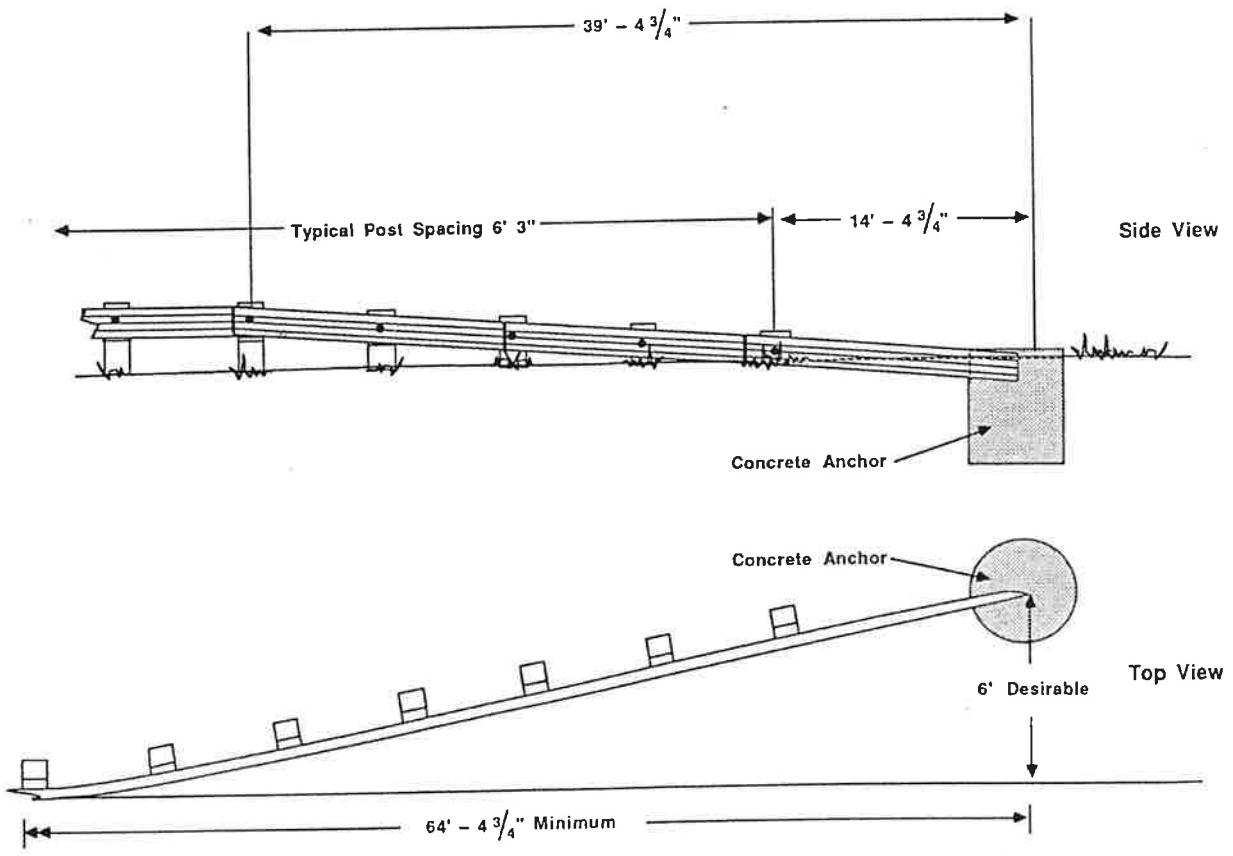


Figure 2



Typical Guardrail Installation

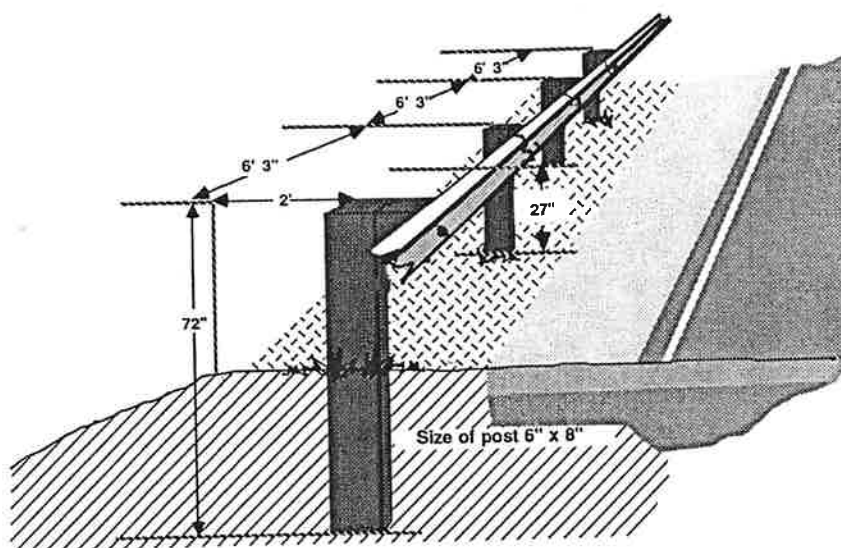


Figure 3

1. Splices or overlapped beam should be in the direction of vehicle travel.
2. Use block-outs on every post.
3. Provide flat surface on round posts and use large nail on square posts to keep block-outs from rotating.
4. Post spacing is 6' 3".
5. Height of beam is measured from top of beam to ground (27").
6. Hinge or breakpoint of slope should be at least 2' from back of post.

Adequate offsets Guardrails must be placed far enough from the fixed object they are shielding to avoid bending around the object, snagging or abruptly stopping the vehicle when impacted. This is normally four feet.

Post spacing Posts spaced too far apart may allow the vehicle to go over or through the guardrail. They also may allow the guardrail to deflect too far, causing the vehicle to impact the hazardous object. Standard spacing for wood posts is six feet three inches.

Post embedment If there is too little soil around the posts, or the posts are too short, then the vehicle may push the guardrail over. There must be at least two feet of soil behind the post. Standard six-by-eight inch wood posts are five and one-half to six feet in length. This normally allows three and one-half to four feet of post to be buried.

Correct beam splicing Beams should be lapped in the direction of the traffic. When beams are spliced in the wrong direction, against the flow of traffic, the vehicle may snag the beam. Proper splice hardware (bolts, washers, etc.) must be used to develop full beam strength.

Block-Outs The beam must be connected to wood block-outs. The block-outs prevent a vehicle from snagging on the post when the beam is hit. Wood block-outs may be made from a 14 inch section of six-by-eight inch post.

Transition section If the transition section is too weak and the vehicle strikes it, then the vehicle may penetrate the guardrail and hit the fixed object. Standard spacing for wood posts in transition sections is three feet, one and one-half inches.

Surrounding conditions The area in front of the guardrail should be flat and clear of vegetation and debris. Any curbs, dikes, sidewalks or other objects which might provide a ramp for a vehicle to go up and over the guardrail should be removed or accounted for in the guardrail design. If snow is likely to become packed in front of the guardrail and could lead to vehicle ramping, maintenance plans should be developed to remove it.



Summary

This bulletin discusses key factors in roadside safety. The most desirable condition is a clear, flat roadside. The size of the clear zone needed depends on traffic volume and speed, and roadway characteristics. Whenever possible hazardous objects in the roadside should be removed, relocated or altered to make them less hazardous. Only if a barrier will be a smaller hazard than the object, should a barrier be considered.

When guardrail will be used it should:

- be long enough to shield the hazard effectively
- be far enough from the hazard to allow room for the beam to deflect the expected distance
- use proper post spacing and use block-outs
- be the proper height
- be spliced in the direction of traffic
- be ended with a properly designed and anchored end section
- use adequately stiff and properly anchored transition sections of the proper height
- have posts which are embedded in enough soil
- be free of debris, curbs, snow, and other conditions which create a ramp for vehicles

Sources

Facilities Development Manual, Wisconsin Department of Transportation, current.

Functional Requirements of Highway Safety Features, U.S. Department of Transportation, Federal Highway Administration (USDOT FHWA), Dec., 1981.

Guide for Erecting Mailboxes on Highways, American Association of State Highway and Transportation Officials (AASHTO), 1985.

Guide for Selecting, Locating and Designing Traffic Barriers, AASHTO, 1977.

Improving Guardrail Installations on Local Roads and Streets, USDOT FHWA, Jan., 1986.

Maintenance of Highway Safety Hardware, USDOT FHWA, June, 1983.

Technology News, Guardrails for Secondary Roads, Local Transportation Information Center, Iowa State University Extension, March, 1986.

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