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4 RURAL HIGHWAYS

Of the nearly 6.3 million km of highways in the United States, nearly 5.0 million km, or about 80 percent, are rural arterials, collectors, and local roads. Most of the rural highway system consists of two-lane rural roads, many of which were originally constructed as farm-to-market roads. While this vast system accounts for only about 31 percent of the travel on all roads, these roads are the most problem related in the nation's road system. Rural arterial, collector, and local roads have fatality rates about two to three times higher than other types of roads. This situation results from a combination of high speeds and less than desirable design features that characterize these roads.

Many of our rural highways are changing. Traffic volumes have grown significantly. Longer, wider, and heavier trucks now travel on rural highways. Adjacent development has resulted in more points of access and conflict. Vehicle operating speeds have increased on many rural highways. Utilities and other potentially dangerous fixed objects have been installed on roadsides. More vehicles are parked along the highway near activity centers or recreational points of interest in rural areas. Rural highways have also experienced increases in pedestrian and bicycle traffic. All of these factors affect safety. For many highways, what was acceptable when the road was originally designed 30 or 40 years ago is now substandard.

Because of the conditions described above, the rural road system presents the most challenges for providing a safe highway system. The vast size of the rural highway network precludes the wide-scale implementation of desirable safety design and operational features. Hence, designers and operators must seek cost-effective solutions to address problem locations, both existing and potential. This chapter presents concepts, guidelines, and considerations for optimizing safety on rural highways. As with all other material in this guide, the reader should refer to the appropriate design manuals and policies for more complete information.

Roadway Design and Operational Considerations

Continuity of Design and Operations

Drivers' experiences with the highway, roadside, and operational features along the road are the factors that establish their expectations and influence their behavior. The concept of continuity of design and operations suggests that drivers will react in a consistent manner to familiar situations; conversely, if drivers experience new situations or situations they are not expecting, their reactions are often delayed and can be detrimental. Therefore, the highway should provide a design and environment consistent with the driving tasks required. Planners and designers need to ensure that drivers' expectations are not violated when the characteristics of the highway environment change. When the highway characteristics change, which frequently occurs on rural highways, drivers need to be alerted to the changed condition and provided the safest highway environment possible.

All designs should strive for the highest practical standards. The guidance provided in the next section sets minimum acceptable values. *Safer values, however, should be provided whenever it is cost-effective to do so.*

Design Speed

As discussed in chapter 2, the key to design decisions concerning geometric, roadside, and operational improvements is the selection of an appropriate design speed. Design speed can be developed through guidance in *A Policy on Geometric Design of Highways and Streets* or Transportation Research Board (TRB) Special Report 214, *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation*.[1,2] However, design speed should never be selected to be lower than the legal driving speed of the highway. Possible conflicts can occur on older highways when the original design speed is lower than the current legal speed. In these cases, an appropriate, higher design speed should be selected and substandard elements identified and addressed. The guidance provided in this document is directed at how engineers and traffic specialists can address the various substandard features that remain.

Design Criteria

Each highway agency should develop design criteria to be used on resurfacing, restoration, and rehabilitation (3R) projects. TRB Special Report 214 provides general guidance for these criteria based on the selected design speed and traffic volumes. Of particular concern are lane and shoulder widths and the horizontal and vertical alignments.

Lane and Shoulder Widths. Total roadway width is among the most important cross-section considerations in the safety performance of a two-lane highway. Wider lanes or shoulders normally result in fewer crashes. Table 4-1, extracted from TRB Special Report 214, contains suggested values for the travel lane and a combined lane and shoulder width, both of which consider the amount of truck traffic and the average daily traffic (ADT). As shown in table 4-1, separate values for shoulder width are not given, but a value for combined lane and shoulder width is. The research done for TRB Special Report 214 established relationships between lane and shoulder width combinations and expected crash rates that showed that, generally, an additional foot of lane widening was more beneficial in crash reduction than a foot of shoulder widening. This relationship should be used for both

Table 4-1. Minimum lane and shoulder widths for two-lane rural highways recommended in TRB Special Report 214, *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation.*[2]

Design Year Volume (ADT)	Running Speed[a] (km/h)	10 Percent or More Trucks[b]		Less Than 10 Percent Trucks	
		Lane Width (m)	Combined Lane and Shoulder Width[c] (m)	Lane Width (m)	Combined Lane and Shoulder Width[c] (m)
Up to 750	Under 80	3.0	3.6	2.7	3.3
	80 and over	3.0	3.6	3.0	3.6
751–2,000	Under 80	3.3	3.9	3.0	3.6
	80 and over	3.6	4.5	3.3	4.2
More than 2,000	All	3.6	5.4	3.3	5.1

[a] *Highway segments should be classified as "under 80" only if most vehicles have an average speed of less than 80 km/h over the length of the segment.*
[b] *For this comparison, trucks with six or more tires are defined as heavy vehicles.*
[c] *This is 0.3 meter less for highways on mountainous terrain.*

reconstruction and 3R projects where wider lane width can be achieved with minimal expense, even at the sacrifice of some shoulder width. An example would be a project that called for widening an existing 6-m-wide traveled way of a two-lane roadway. If the design year ADT is over 2,000 and trucks constitute more than 10 percent of the traffic, then the minimum lane and shoulder width suggested in TRB Special Report 214 is 5.5 m. If, however, the widening were limited to a 9-m-wide roadway section, the better cross section would be two 3.6-m lanes with 0.9-m shoulders rather than two 3.3-m lanes with 1.2-m shoulders, even though the latter would satisfy most 3R standards. The relationships also show that there is a safety benefit to stabilized versus nonstabilized shoulders, in addition to the standard benefits of travel lane support and reduced maintenance.

Horizontal and Vertical Alignment. Horizontal curves represent a considerable safety problem on rural two-lane roads. Crash studies indicate that curves experience a higher crash rate than tangents, with rates ranging from 1.5 to 4 times higher than tangents of similar length and volume. Also, crashes on curves are more likely to result in death or serious injury than those on tangents because of the type of crashes that occur on curves.[3]

A 1991 informational guide developed for the FHWA provides guidelines for designing horizontal curves on new highway sections and for the reconstruction and upgrading of existing curves on two-lane rural roads.[4] The informational guide also provides procedures and general data that can be used for determining benefits from various combinations of curve improvements. This guidance supplements the policies contained in *A Policy on Geometric Design of Highways and Streets*.[1] The design guidelines for new construction are as follows:

- Consistent roadway sections should be provided.
- Large central angles should be avoided wherever possible.
- The use of controlling curvature (i.e., maximum allowable curvature for a given design speed) should be minimized.
- Spiral transition curves should be used as a routine part of design, particularly for controlling curves and for curves on highways with high design speeds (100 km/h or greater).
- High-quality roadside designs should be routinely provided, particularly on sharper curves.
- An adequate amount of superelevation should be used on all curves.
- Other potentially dangerous features should not be located at or near horizontal curves because of driver difficulty in tracking curvature.
- Adequate pavement and shoulder conditions shall be provided, particularly on sharper curves where lateral acceleration and friction demand are the greatest.

TRB Special Report 214 provides guidance for evaluating existing horizontal and vertical curves during the planning and design of 3R projects. For horizontal curvature, the TRB Special Report 214 guidance provides for retaining without further evaluation existing curves that have approaching-vehicle running speeds that are within 25 km/h of the selected design speed. For vertical curves, the guidance provides for retaining without further evaluation existing curves with design speeds within 32 km/h of the 85th percentile running speeds of vehicles on the crest if there is no hidden major hazard. Again, these criteria should not be used if the alignment could be improved cost effectively. Where horizontal curves are retained that do not meet the legal speed limit, curve warning signs should be used. For sharper curves, selected operational features such as speed advisory plates, upgraded pavement markings, or delineators can be used to give the driver additional information on the sharpness of the curve, thereby mitigating some of the potential danger. The designer should also consider improvements that would reduce the likelihood or severity of a crash, such as widening shoulders or improving the clear zone on the outside of the curve by removing fixed objects or flattening steep slopes.

A special case for horizontal curvature is a series of curves of similar sharpness. The first curve in each approach should receive special attention so that, once the driver has safely passed through it, the change in alignment has prepared the driver for the remaining curves. Any curve within the series that is significantly sharper than the others should also be treated specially.

Although individual horizontal and vertical curves may meet design standards or are acceptable under the guidance in TRB Special Report 214,[2] their use in combination with each other is important and must be considered to avoid creating an unsafe situation. This is critical on two-lane, high-speed highways.

Speed Zones

Reduced speed zones are defined as sections of the highway where the character or geometrics of the highway require posting speed limits below the statutory or overall normal speed limit of the highway. Reduced speed zones are commonly used on sections of a rural highway where development, such as towns and businesses, substantially changes the character of the highway environment. Along such sections, there is a significant increase in the number of access points, potential conflict points, pedestrians, and bicycle traffic, all of which warrant a reduced speed limit. It is desirable to coordinate establishing these reduced speed zones with the community affected to ensure that community concerns are addressed and to facilitate enforcement of the speed limits.

One method of determining an appropriate speed limit for such a zone would be to conduct spot speed studies and determine the 85th percentile speed in accordance with guidelines set forth in the *MUTCD*.[5] Recent research has found, however, that the 85th percentile speed was between 10 and 23 km/h over the speed limit and between 6 to 11 km/h higher than the mean speed. Any design discontinuities in the proposed reduced speed zone should be adequately considered and addressed. Whenever possible, substandard features should be improved or warnings provided.

Reduced speed zones are not appropriate for individual substandard features. They would violate the driver's expectations and generate disregard for the reduced speed zone signing. More information on the establishment of speed limits is presented under "Operational Features" in chapter 5.

Passing Zones

Passing zones are an essential element of the two-lane, two-way rural highway. Information on providing adequate sight distance for passing is provided in *A Policy on Geometric Design of Highways and Streets*;[1] criteria to establish no-passing zones and standards for marking them are contained in the *MUTCD*.[5]

It is desirable to provide as many passing opportunities as possible on a section of highway. This is often a good practice in areas where there are limited opportunities to pass or on highways that may have slow-moving traffic. However, the principles of design consistency should be considered. The use of minimum-length passing zones intermixed with long passing zones can violate a driver's expectations, especially if the driver has become accustomed to long passing sections. Short or minimal passing zones should not be intermixed if adequate long passing sections are available. Short passing zones may be necessary in mountainous terrain to permit passing of slow trucks and recreational vehicles when truck passing lanes cannot be provided.

Passing Lanes

Passing lanes are lanes added intermittently over a portion of a conventional two-lane road. A passing lane can be used on either rolling or level terrain when passing restrictions exist because of limited sight distances or high volumes of oncoming traffic. A lack of frequent sections with adequate passing sight distance combined with high traffic volumes—especially if the traffic includes large, slower-moving trucks and recreational vehicles—results in increased operational delays and potential safety conflicts.[6] The justification for increasing the frequency of passing opportunities is usually based on a level-of-service analysis using procedures in chapter 8 of the *Highway Capacity Manual*.[7] Measuring traffic traveling in platoons (traffic with headway gaps of 5 seconds or less) can also be helpful in establishing need and identifying potential sites for passing lanes. Evaluating the need for passing improvements should consider traffic operations over an extended road length, usually at least 8 km.

The location of passing lanes should appear logical to the driver, such as on extended segments of road with restricted sight distance. The value of passing lanes is more obvious to the driver where passing sight distance is restricted than on long tangent sections that already provide good passing opportunities. In some cases, a passing lane on a long tangent may encourage slow drivers to speed up, thus reducing the lane's effectiveness. Passing lanes also are not appropriate for highway sections with low-speed horizontal curves that restrict speeds for all drivers. Other location factors include the need to provide a minimum sight distance of 300 m at the lane addition and lane drop tapers and, if possible, to avoid locations that include major intersections or high-volume driveways.

The optimal length of a passing lane is 0.8 to 1.6 km, which does not include the taper length for the lane addition and lane drop. The lane drop taper should be designed in accordance with the requirements in section 3B-8 of the *MUTCD*.[5] The lane addition is usually one-half to two-thirds the length of a lane drop taper.

Signing is needed to convey information to drivers in advance of the passing lane, at the lane addition, and before the lane drop. The recommended layout of signs and markings for a passing lane is similar to that of a climbing lane, as shown in figure 4-1.

Passing for vehicles traveling in the opposite direction to a passing lane may be either permitted or prohibited. This should be determined on a site-by-site review of unusual geometrics, roadside development, and traffic volumes, in addition to sight-distance limitations. Through the appropriate use of signs and centerline markings, passing in the opposite direction should be prohibited in sections when there are frequent left turns from the passing lane.[6]

Climbing Lanes

Steep upgrades cause large trucks to decelerate and bicyclists to wobble. The maximum sustained speed that can be maintained by a large truck depends primarily on the length and steepness of the grade and the truck's mass/power ratio.

Climbing lanes, constructed as an extra lane on the upgrade side of a two-lane highway and paved shoulders for bicyclists, should be considered when the critical length of grade is exceeded, that is, where the length of grade causes a reduction of 15 km/h or more in the speed of a heavy truck. The current critical length-of-grade criterion is based on the performance characteristics of a typical 180 kg/kW truck. Research results indicate that many trucks perform significantly better on upgrades than this typical 180 kg/kW truck.[8,9] A new, simplified method was developed to predict the speed loss of trucks as they travel up a grade.[10] Despite its limitations, this method can be used as another tool to decide whether a truck climbing lane should be designed and constructed. Bicyclists require a 1.8- to 2.4-m paved shoulder for climbing any time the grade exceeds 2 percent or 30 m.

Roadsides and Medians

Roadside Features and Safety Appurtenances

The concepts of the forgiving roadside and mitigation of substandard highway features are discussed in chapter 2 of this guide. These concepts apply to the design and upgrading of safety features on all rural highways, but the extent to which they can be reasonably applied may vary depending on the nature of the road, terrain, character of traffic, available right-of-way, and extent of the proposed project.

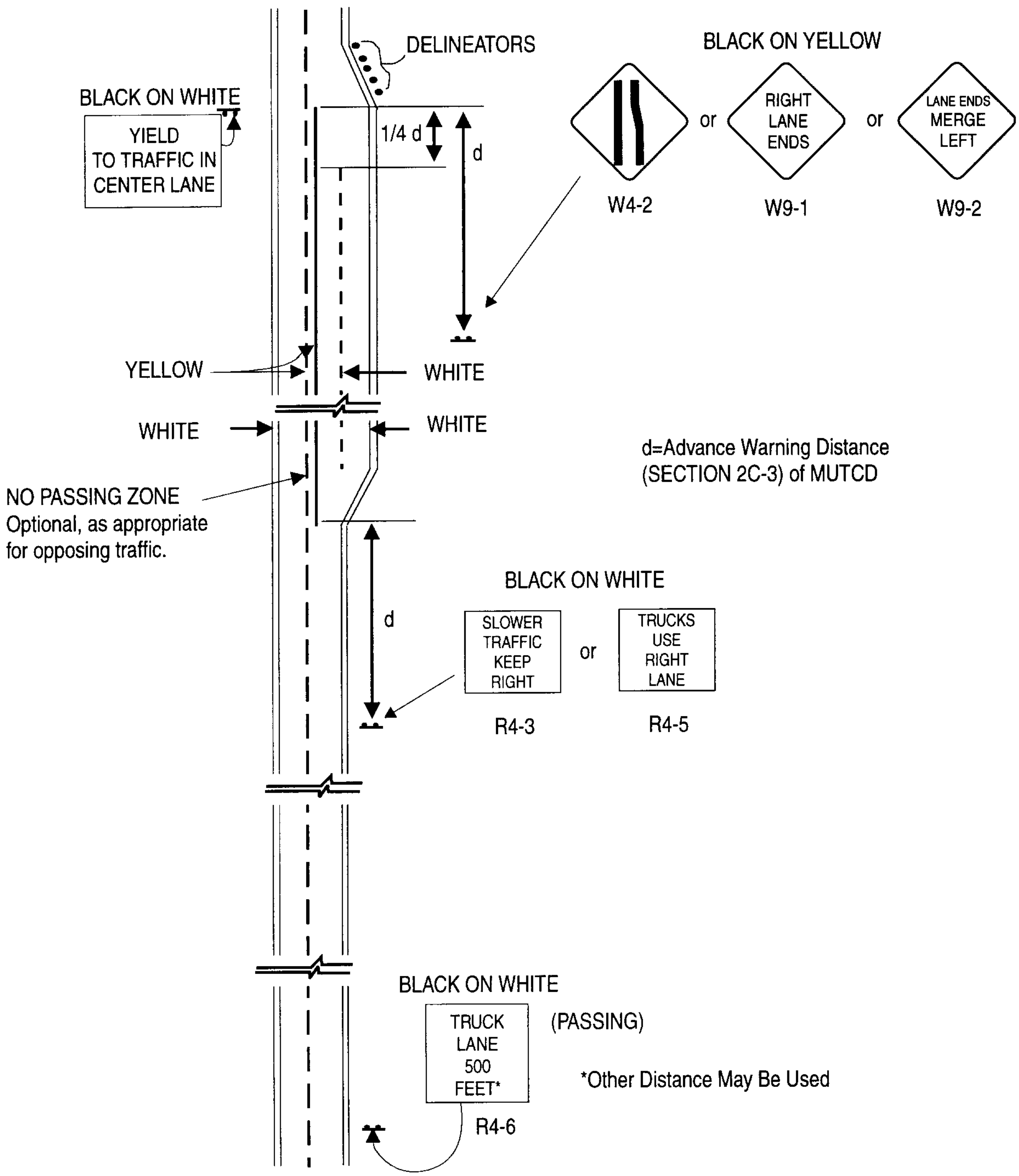

Figure 4-1. Recommended signing and marking practices for passing lanes.

Traversable Roadsides and Medians. Side slopes should be built as flat as practical, consistent with the design speed, traffic volume, and horizontal and vertical curvature of the highway. Side slopes of 1:4 are considered the steepest slopes that permit vehicle control. On new construction, 1:6 or flatter side slopes are desirable. Whenever practical, the same criteria should be applied to reconstruction and 3R projects; however, constraints such as restricted right-of-way, wetlands, limited funds, and existing features (bridges, drainage structures, ditches, etc.), may limit design options.

Although it is desirable to maintain continuity of the roadside, in many areas spot improvements to roadside slopes can be very effective in improving highway safety. The parallel and perpendicular slopes created by the driveways shown in figure 4-2 are potential problems. Locations where flattening steep slopes should be considered include the following:

- The outside of curves
- Along approaches to intersections, access points, and median crossovers
- Around bridge piers, drainage culverts, and barriers, particularly near the terminals

Attention should also be paid to driveways and access points. Flattened slopes of 1:6 or flatter, with sloped openings or grates for small drainage pipes, are desirable. Walls and steep berms should not be used.

In roadway upgrading, reconstruction, and 3R projects, it may not always be practical to improve all locations that need improving. Providing flat, traversable side slopes free of fixed objects can often help mitigate the effects of substandard roadside features. Mitigation includes even the removal of small trees, which can cause an errant vehicle to vault, resulting in more serious injury to the occupants.

Traversable Drainage Features. On new construction, drainage inlets should be designed to be traversable by bicycles as well as automobiles when they are in the path of traffic or the potential path of an errant vehicle, as shown in figure 4-3. Existing inlets that project more than 100 mm above the ground, as shown in figure 4-4, can snag the undercarriage of a vehicle or initiate vehicle instability and, in some instances, strike bicyclists if bars are

Figure 4-2. Undesirable steep slopes, both parallel and perpendicular to the highway.

installed improperly. Inlets that are potential problems should be reconstructed to be traversable. Berms or dikes used to improve hydraulic efficiency should be avoided unless designed to be traversable.

Potential problem inlets that are located off the traveled way and that cannot be improved should be delineated with an appropriate device. Marking an inlet will not reduce the severity of any crash that does occur, but may help a driver avoid striking it.

In many situations, drainage ditches will be required adjacent to the traveled way. This is common where development occurs along the highway and when widening a facility within a limited right-of-way. Often, these ditches are deep enough to keep the water under the level of the highway and cannot be designed to be traversable because of limited space, as shown in figure 4-5. This type of ditch and the associated headwalls or culvert openings can lead to severe impacts and

Figure 4-3. Traversable drainage inlet.

Figure 4-4. Existing inlet projecting more than 100 mm above the ground.

rollover accidents. A subsurface drainage system should be considered or, where the severity of the ditch warrants, a roadside barrier system should be used for protection. Subsurface drainage systems have the advantage of providing a safer traversable condition, particularly around access points where barriers must terminate.

Culvert openings for new highway construction should be designed to be traversable if they could be struck by an errant vehicle. Side slopes within the clear zone should also be traversable. However, achieving that may require additional grading to accommodate standard traversable culvert openings. Some examples of traversable culvert openings are provided in the *Roadside Design Guide*.[11]

When practical, substandard culvert openings located within the designated clear zone of existing highways should be reconstructed to be traversable or, at a minimum, extended beyond the clear zone to reduce the possibility of the culvert contributing to the severity of a crash.

Culvert extensions must be well graded to ensure that the side slopes remain traversable. Culverts under approach roads and intersections should also be traversable even if they are outside the designated clear zone, especially if an errant vehicle could be guided into the culvert end by the drainage ditch, as shown in figure 4-6.

Sign and Luminaire Supports. All sign supports that can be reached and struck by a vehicle should be crashworthy. Breakaway

Figure 4-5. Nontraversable ditch.

Figure 4-6. An errant vehicle can be guided by a ditch into a culvert opening even though outside the clear zone.