Florida Department of Transportation

# Manual of Uniform Minimum Standards for Design, Construction and Maintenance for Streets and Highways

(Commonly known as the “Florida Greenbook”)

http://www.dot.state.fl.us/rddesign/FloridaGreenbook/FGB.shtm

**FDOT Office**
Office of Design
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# USER REGISTRATION

## *Manual of Uniform Minimum Standards for Design, Construction and Maintenance for Streets and Highways*

(Commonly known as the ***Florida Greenbook***)

**2016 Edition**

To: Florida Greenbook Users

The Department of Transportation utilizes a contact database that enables the Department to e-mail important information to registered users on topics selected by each user. The database allows a user to update their physical address, e-mail address, topics of interest, and any other information in their profile at any time.

All Florida Greenbook users must register their e-mail addresses in this contact database in order to receive updates, notices, design memos, or other important information concerning the Department's design manuals. Users must register at the following link:

http://www.fdot.gov/designsupport/ContactDatabase.shtm

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# FLORIDA GREENBOOK COMMITTEE MEMBERS

# 2016

The Florida Greenbook Advisory Committee is composed of four professional engineers within each of the Department of Transportation's seven district boundaries as described in Section 336.045(2), Florida Statutes (F.S.).

**Section 336.045, Florida Statutes. Uniform minimum standards for design, construction, and maintenance; advisory committees.**

**(2)** An advisory committee of professional engineers employed by any city or any county in each transportation district to aid in the development of such standards shall be appointed by the head of the department. Such committee shall be composed of: one member representing an urban center within each district; one member representing a rural area within each district; one member within each district who is a professional engineer and who is not employed by any governmental agency; and one member employed by the department for each district.

Contact information for the Florida Greenbook Advisory Committee members can be found on the Florida Greenbook web page:

http://www.fdot.gov/roadway/FloridaGreenbook/FGB.shtm

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Chapter Subcommittee member information and activities can also be found on the Florida Greenbook webpage:

http://www.fdot.gov/roadway/FloridaGreenbook/FGB.shtm

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| 3. Geometric Design | Howard Webb |
| 4. Roadside Design | Charles Ramdatt |
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| 17. Bridges and Other Structures | Keith Bryant |
| 18. Signing and Marking | Gail Woods |
| 19. Traditional Neighborhood Development | Rick Hall |
| 20. Drainage | George Webb |

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# INTRODUCTION

The purpose of this Manual is to provide uniform minimum standards and criteria for the design, construction, and maintenance of all public streets, roads, highways, bridges, sidewalks, curbs and curb ramps, crosswalks (where feasible), bicycle facilities, underpasses, and overpasses used by the public for vehicular and pedestrian traffic as directed by ***Sections 20.23(4)(a), 316.0745, 334.044(10)(a), and 336.045, F.S.***

In the following statutory excerpts, the term "Department" refers to the Florida Department of Transportation.

**Section 20.23, F.S. Department of Transportation.** There is created a Department of Transportation which shall be a decentralized agency.

**(3)(a)** The central office shall establish departmental policies, rules, procedures, and standards and shall monitor the implementation of such policies, rules, procedures, and standards in order to ensure uniform compliance and quality performance by the districts and central office units that implement transportation programs. Major transportation policy initiatives or revisions shall be submitted to the commission for review.

**Section 316.0745, F.S. Uniform signals and devices. –**

**(1)** The Department of Transportation shall adopt a uniform system of traffic control devices for use on the streets and highways of the state. The uniform system shall, insofar as is practicable, conform to the system adopted by the American Association of State Highway Officials and shall be revised from time to time to include changes necessary to conform to a uniform national system or to meet local and state needs. The Department of Transportation may call upon representatives of local authorities to assist in the preparation or revision of the uniform system of traffic control devices.

**Section 334.044, F.S. Department; powers and duties.** The department shall have the following general powers and duties:

**(10)(a)** To develop and adopt uniform minimum standards and criteria for the design, construction, maintenance, and operation of public roads pursuant to the provisions of ***Section, 336.045, F.S***.

**Section 336.045, F.S. Uniform minimum standards for design, construction, and maintenance; advisory committees.**

**(1)** The department shall develop and adopt uniform minimum standards and criteria for the design, construction, and maintenance of all public streets, roads, highways, bridges, sidewalks, curbs and curb ramps, crosswalks, where feasible, bicycle ways, underpasses and overpasses used by the public for vehicular and pedestrian traffic. In developing such standards and criteria, the department shall consider design approaches which provide for the compatibility of such facilities with the surrounding natural or manmade environment; the safety and security of public spaces; and the appropriate aesthetics based upon scale, color, architectural style, materials used to construct the facilities, and the landscape design and landscape materials around the facilities.

**(4)** All design and construction plans for projects that are to become part of the county road system and are required to conform with the design and construction standards established pursuant to subsection (1) must be certified to be in substantial conformance with the standards established pursuant to subsection (1) that are then in effect by a professional engineer who is registered in this state.

These standards are intended to provide basic guidance for developing and maintaining a highway system with reasonable operating characteristics and a minimum number of hazards.

Standards established by this Manual are intended for use on all new and resurfacing construction projects off the state highway and federal aid systems. Unless specified otherwise herein, it is understood that the standards herein cannot be applied completely to all reconstruction and maintenance type projects. However, the standards shall be applied to reconstruction and maintenance projects to the extent state or federal statute requires and that economic and environmental considerations and existing development will allow.

The Federal Highway Administration's ***Manual on Uniform Traffic Control Devices, 2009 Edition (MUTCD),*** has been adopted by ***Rule 14 – 15.010, F.A.C*****.**, and establishes a uniform system of traffic control devices. The ***Manual on Uniform Traffic Control Devices (2009 Edition with Revision Numbers 1 and 2, May 2012, MUTCD)*** includes additional requirements.

When this Manual refers to guidelines and design standards given by current American Association of State Highway and Transportation Officials (AASHTO) publications, these guidelines and standards shall generally be considered as minimum criteria. The Department may have standards and criteria that differ from the minimum presented in this Manual or by AASHTO for streets and highways under its jurisdiction. A county or municipality may substitute standards and criteria adopted by the Department for some or all portions of design, construction, and maintenance of their facilities. Department standards, criteria, and manuals must be used when preparing projects on the state highway system or the national highway system.

Criteria and standards set forth in other manuals, which have been incorporated by reference, shall be considered as requirements within the authority of this Manual.

This Manual is intended for use by qualified engineering practitioners for the communication of standards and criteria (including various numerical design values and use conditions). The design, construction, and maintenance references for the infrastructure features contained in this Manual recognize many variable and often complex process considerations. The engineering design process, and associated use of this Manual, incorporates aspects of engineering judgment, design principles, science, and recognized standards towards matters involving roadway infrastructure.

Users of this Manual are cautioned that the strict application of exact numerical values, conditions or use information taken from portions of the text may not be appropriate for all circumstances. Individual references to design values or concepts should not be used out of context or without supporting engineering judgment.

The contents of this Manual are reviewed annually by the Florida "Greenbook" Advisory Committee. Membership of this committee is established by the above referenced ***Section 336.045(2), F.S.*** Comments, suggestions, or questions may be directed to any committee member.

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# POLICY

Specific policies governing the activities of planning, design, construction, reconstruction, maintenance, or operation of streets and highways are listed throughout this Manual. All agencies and individuals involved in these activities shall be governed by the following general policies:

- Each public street and highway, and all activities thereon, shall be assigned to the jurisdiction of some highway agency. Each highway agency should establish and maintain a program to promote safety in all activities on streets and highways under its jurisdiction.

- Highway safety shall be considered and given a high priority in order to promote the achievement of the maximum safety benefits for given expenditures and efforts.

- The provision for safe, high-quality streets and highways, and maximum transit opportunities should take priority over the provision for the maximum highway mileage obtainable for the available funds.

# OBJECTIVES

The planning, design, construction, reconstruction, maintenance, and operation of streets and highways should be predicated upon meeting the following objectives:

- Develop and maintain a highway system that provides the safest practicable environment for motorists, cyclists, pedestrians, and workers.

- Establish and maintain procedures for construction, maintenance, utility, and emergency operations that provide for safe highway and transit operating conditions during these activities.

- Provide streets and highways with operating characteristics that allow for reasonable limitations upon the capabilities of vehicles, drivers, cyclists, pedestrians, and workers.

- Provide uniformity and consistency in the design and operation of streets and highways.

- Provide for satisfactory resolution of conflicts between the surface transportation system and social and environmental considerations to aid neighborhood integrity.
- Reconstruct or modify existing facilities to reduce the hazard to the highway users.
- Reduce the deaths, injuries, and damage due to highway crashes.

Additional general and specific objectives related to various topics and activities are listed throughout this Manual. Where specific standards or recommendations are not available or applicable, the related objectives shall be utilized as general guidelines.

# DEFINITIONS OF TERMS

The following terms shall, for the purpose of this Manual, have the meanings respectively ascribed to them, except instances where the context clearly indicates a different meaning. The ***Manual on Uniform Traffic Control Devices (2009 Edition with Revision Numbers 1 and 2, May 2012, MUTCD)*** includes additional information on terms used in conjunction with the application of the ***MUTCD***.

**Alley** A narrow right of way to provide access to the side or rear of individual land parcels.

**Annual Average Daily Traffic (AADT)** The total volume of traffic on a highway segment for one year, divided by the number of days in the year. This volume is usually estimated by adjusting a short-term traffic count with weekly and monthly factors.

**Average Daily Traffic (ADT)** The total traffic volume during a given time period (more than a day, less than a year) divided by the number of days in that time period.

**Auxiliary Lane** A designated width of roadway pavement marked to separate speed change, turning, passing, and climbing maneuvers from through traffic.

**Average Running Speed** For all traffic, or component thereof, the summation of distances divided by the summation of running times.

**Bicycle Lane (Bike Lane)** A portion of a roadway that has been designated for preferential use by bicyclists by pavement markings, and if used, signs. They are one-way facilities that typically carry traffic in the same direction as adjacent motor vehicle traffic.

**Boarding And Alighting (B&A) Area** — A firm, stable, slip resistant surface that accommodates passenger movement on or off a transit vehicle.

**Clear Zone** — The roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, recoverable slope, non-recoverable slope, clear runout area, or combination thereof. The desired width is dependent upon the traffic volumes and speeds, and on the roadside geometry. Note: The aforementioned "border area" is not the same as "border width". Also, see Horizontal Clearance.

**Corridor** — A strip of land between two termini within which traffic, topography, environment, population, access management, and other characteristics are evaluated for transportation purposes.

**Crosswalk** — Portion of the roadway at an intersection included within the connections of lateral lines of the sidewalks on opposite sides of the highway, measured from the curbs or in the absence of curbs from the traversable roadway. Crosswalks may also occur at an intersection or elsewhere distinctly indicated for pedestrian crossing.

**Design Hour Volume (DHV)** — Traffic volume expected to use a highway segment during the design hour of the design year. The DHV is related to the AADT by the “K” factor. It includes total traffic in both directions of travel.

**Directional Design Hour Volume (DDHV)** — Traffic volume expected to use a highway segment during the design hour of the design year in the peak direction.

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|---|---|
| **Design Speed** | A selected speed used to determine the various geometric design features of the roadway. The selected design speed should be a logical one with respect to the topography, anticipated operating speed, adjacent land use, and functional classification of the highway. |
| **Design Vehicle** | A vehicle, with representative weight, dimensions, and operating characteristics, used to establish highway design controls for accommodating vehicles of designated classes. |
| **Driveway** | An access from a public way to adjacent property. |
| **Expressway** | A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at major intersections. |
| **Federal Aid Highway** | A highway eligible for assistance under the United States Code Title 23 other than a highway classified as a local road or rural minor collector. |
| **Freeway or Limited Access Highway** | An expressway with full control of access. |
| **Frontage Road or Street** | A street or highway constructed adjacent to a higher classification street or other roadway network for the purpose of serving adjacent property or control access. |
| **Grade Separation** | A crossing of two roadways or a roadway and a railroad or pedestrian pathway at different levels. |
| **High Speed** | Speeds of 50 mph or greater. |

**High-Speed Rail** — Intercity passenger rail service that is reasonably expected to reach speeds of at least 110 miles per hour.

**Highway, Street, or Road** — General terms, denoting a public way for purposes of traffic, both vehicular and pedestrian, including the entire area within the right of way. The term street is generally used for urban or suburban areas.

**Horizontal Clearance** — Lateral distance from edge of motor vehicle travel lane to a roadside object or feature.

**Intersection** — The general area where two or more streets or highways join or cross.

**May** — A permissive condition. Where "may" is used, it is considered to denote permissive usage.

**Maintenance** — A strategy of treatments to an existing roadway system that preserves it, retards future deterioration, and maintains or improves the functional condition.

**New Construction** — The construction of any public way (paved or unpaved) where none previously existed, or the act of paving any previously unpaved road, except as provided in Chapter 3, Section A of these standards.

**Operating Speed** — The rate of travel at which vehicles are observed traveling during free-flow conditions.

**Paratransit** — Comparable transportation service required by the ADA for individuals with disabilities who are unable to use fixed route transportation systems.

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|---|---|
| **Pedestrian Access Route** | A continuous and unobstructed path of travel provided for pedestrians with disabilities within or coinciding with a pedestrian circulation path. |
| **Pedestrian Circulation Path** | A prepared exterior or interior surface provided for pedestrian travel in the public right of way. |
| **Preferential Lane** | A street or highway lane reserved for the exclusive use of one or more specific types of vehicles or vehicles with at least a specific number of occupants. |
| **Public Way** | All public streets, roads, highways, bridges, sidewalks, curbs and curb ramps, crosswalks (where feasible), bicycle facilities, underpasses, and overpasses used by the public for vehicular and pedestrian traffic. |
| **Ramp** | 1) Includes all types, arrangements, and sizes of turning roadways that connect two or more legs at an interchange. 2) A combined ramp and landing to accomplish a change in level at a curb (curb ramp). |
| **Reconstruction** | Any road construction other than new construction. |
| **Recovery Area** | A clear zone that includes the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. |

**Residential Streets**

Streets primarily serving residential access to the commercial, social, and recreational needs of the community. These are generally lower volume and lower speed facilities than the primary arterial and collector routes of the local system "or as adopted by local government ordinance".

**Resurfacing**

Work to place additional layers of surfacing on highway pavement, shoulders, bridge decks and necessary incidental work to extend the structural integrity of these features for a substantial time period.

**Right Of Way**

A general term denoting land, property or interest therein, usually in a strip, acquired or donated for transportation purposes. More specifically, land in which the State, the Department, a county, a transit authority, municipality, or special district owns the fee or has an easement devoted to or required for use as a public road.

**Roadway**

The portion of a street or highway, including shoulders, for vehicular use. A divided highway has two or more roadways.

**Rural Areas**

Those areas outside of urban boundaries. Urban area boundary maps based upon the 2010 Census are located on the Department's Urban Area 1-Mile Buffer Maps,

**Shall or Must**

A mandatory condition. (When certain requirements are described with the "shall" or "must" stipulation, it is mandatory these requirements be met.)

| | |
|---|---|
| **Shared Street** | Specially designed residential or commercial street where space is shared by all users and alignment supports slower vehicle speeds and the perception of shared space. |
| **Shared Roadway** | A roadway that is open to both bicycle and motor vehicle travel. This may be an existing roadway, street with wide curb lanes, or road with paved shoulders. |
| **Shared Use Path** | Paved facilities physically separated from motorized vehicular traffic by an open space or barrier. May be within the highway right of way or an independent right of way, with minimal cross flow by motor vehicles. Users are non-motorized and may include: pedestrians, bicyclists, skaters, people with disabilities, and others. |
| **Should** | An advisory condition. Where the word "should" is used, it is considered to denote advisable usage, recommended but not mandatory. |
| **Slope** | The relative steepness of the terrain, expressed as a ratio or percentage. Slopes may be categorized as positive (backslopes) or negative (foreslopes) and as parallel or cross slopes in relation to the direction of traffic. In this manual slope is expressed as a ratio of vertical to horizontal (V:H). |
| **Surface Transportation System** | Network of highways, streets, and/or roads. Term can be applied to local system or expanded to desired limits of influence. |

**Traditional Neighborhood Development (TND)**

TND refers to the development or redevelopment of a neighborhood or town using traditional town planning principles. Projects should include a range of housing types and commercial establishments, a network of well-connected streets and blocks, civic buildings and public spaces, and include other uses such as stores, schools, and places of worship within walking distances of residences.

**Traffic**

Pedestrians, bicyclists, motor vehicles, streetcars and other conveyances either singularly or together while using for purposes of travel any highway or private road open to public travel.

**Traffic Lane**

Includes travel lanes, auxiliary lanes, turn lanes, weaving, passing, and climbing lanes.

**Travel Lane**

A designated width of roadway pavement marked to carry through traffic and to separate it from opposing traffic or traffic occupying other traffic lanes. Generally, travel lanes equate to the basic number of lanes for a facility.

**Traveled Way**

The portion of the roadway for the movement of vehicles, exclusive of shoulders, berms, sidewalks and parking lanes.

**Turning Roadway**

A connecting roadway for traffic turning between two intersection legs.

**Urban Area**

A geographic region comprising, as a minimum, the area inside the United States Bureau of the Census boundary of an urban place with a population of 5,000 or more persons, expanded to include adjacent developed areas as provided for by Federal Highway Administration regulations. Urban area boundary maps based upon the 2010 Census are located on the Department's Urban Area 1-Mile Buffer Maps.

**Urbanized Area**

A geographic region comprising, as a minimum, the area inside an urban place of 50,000 or more persons, as designated by the United States Bureau of the Census, expanded to include adjacent developed areas as provided for by Federal Highway Administration regulations. Urban areas with a population of fewer than 50,000 persons which are located within the expanded boundary of an urbanized area are not separately recognized.

**Vehicle**

Every device upon, or by which any person or property is or may be transported or drawn upon a traveled way, excepting devices used exclusively upon stationary rails or tracks. Bicycles are defined as vehicles per Section 316.003, Florida Statutes.

**Vertical Clearance**

Minimum unobstructed vertical passage space.

**Very Low-Volume Road**

A road that is functionally classified as a local road and has a design average daily traffic volume of 400 vehicles per day or less.

**Wide Outside Lane**

Through lanes that provide a minimum of 14 feet in width. This lane should always be the through lane closest to the curb or shoulder of the road when a curb is not provided.

# CHAPTER 1

# PLANNING

# CHAPTER 1

# PLANNING

## A INTRODUCTION

Developing and maintaining an efficient multi-modal system requires careful planning by each unit in a transportation agency. This includes both planning for the design and construction of streets and highways and planning for operating the facilities. Overall planning would include a consideration for all aspects of design, construction, and operations (including maintenance) affecting the resulting characteristics of streets and highways. These characteristics will be significantly affected by the degree to which the various demands and requirements on the highway system are satisfied in the initial planning and design.

Successful highway design requires that the role of each new facility in the overall highway system be clearly delineated. The determination and clear definition of the function and classification of each street and highway is also required. Safety and efficiency of new facilities is predicated, to a large extent, on corridor selection and provisions for adequate right of way, alignment, and access control. Initial planning and design should also consider provisions for future modifications and upgrading required by changes in speed, volume, or standards.

Plans for actually operating a new street or highway should be considered in the initial planning and should be closely coordinated with the design of the facility. Development of plans and procedures for successfully operating an existing highway system must include a consideration of all activities affecting the operating characteristics of each street and highway.

Planning, designing, operating, and maintaining a street system has become more complex in recent years. These disciplines must address the relationship to land use and the desire for access to public transit, pedestrian and bicycle traffic, the growing number of elder road users, and the mobility needs of persons with disabilities. This begins in planning and continues throughout the design and operational process.

# B FUNCTIONAL CLASSIFICATION

A determination of the function and operational requirements, and a clear definition of the classification of each new facility are required prior to the actual design.

## B.1 Function

Design of each new street or highway is based upon its function in the highway system. Operational requirements that must be satisfied to fulfill this function are dependent upon the following factors:

### B.1.a Volume

Volume of traffic that must be carried by the facility is a primary factor governing the design. Variations in volume with respect to direction and time should also be evaluated to determine the expected requirements for peak capacities.

### B.1.b Speed

Operating speed (to be maintained) should meet reasonable expectations of the users.

### B.1.c Traveler Characteristics

Unless prohibited by law, a variety of travelers should be expected on all public roads. These could include pedestrians, bicyclists, and motor vehicle operators and passengers. Types and relative volumes of people expected to use the street or highway influence trip characteristics and design features.

### B.1.d Trip Characteristics

Functions of a new facility are, to a large extent, determined by the length and purpose of vehicle trips. Trip characteristics are influenced by land use characteristics and the highway network layout.

#### B.1.e Safety

Functional classification plays an important role in setting expectations and measuring outcomes for safety. Since agencies consider the type of roadway in evaluating the significance of crash rates, functional classification can be used as part of evaluating the relative safety of roadways and the implementation of safety improvements and programs.

#### B.1.f Measures of Level of Service

Level of service (LOS) is essentially a measure of the quality of the operating characteristics of a street or highway. Factors involved in determining the level of service include speed and safety, as well as travel time; traffic conflicts and interruptions; freedom to maneuver; convenience and comfort; and operating costs. Level of service is also dependent upon actual traffic volume and composition of traffic (motor vehicles, trucks, transit, bicyclists, and pedestrians).

The ***Highway Capacity Manual 2010*** provides further information on assessing the traffic and environmental effects of highway projects.

#### B.1.g Access Requirements

Degree and type of access permitted on a given facility is dependent upon its intended function and should conform to the guidelines in ***Chapter 3 – Geometric Design***. Reasonable access control must be exercised to allow a street or highway to fulfill its function.

#### B.1.h Public Transit Use

Both current and planned use by public transit influence design features. Transit vehicles increase capacity on a roadway.

### B.2 Classification

Road classifications are defined in ***Section 334.03 F.S***.. Functional classification is the assignment of roads into systems according to the character of service they provide in relation to the total road network.

### B.2.a Basic Classification

Basic functional categories include arterial, collector, and local roads which may be subdivided into principal, major, or minor levels. These levels may be additionally divided into rural and urban categories. This basic classification system is utilized throughout this Manual.

#### B.2.a.1 Local Road

A route providing service which is of relatively low average traffic volume, short average trip length or minimal through-traffic movements, and high land access for abutting property.

#### B.2.a.2 Collector Road

A route providing service which is of relatively moderate average traffic volume, moderately average trip length, and moderately average operating speed. These routes also collect and distribute traffic between local roads or arterial roads and serve as a linkage between land access and mobility needs.

#### B.2.a.3 Arterial Road

A route providing service which is relatively continuous and of relatively high traffic volume, long average trip length, generally higher operating speed, and high mobility importance. In addition, every United States numbered highway is an arterial road.

### B.2.b Classification Modifications

Design and classification of streets and highways should also be based upon a consideration of highway user expectations. The function of any facility, as perceived by the user, essentially determines the driver's willingness to accept restrictions upon speed, capacity, access, or level of service. Basic classification systems may also be modified by the following variables:

#### B.2.b.1 Urban

Urban area highway users will generally accept lower speeds and levels of service. Economic constraints in urban areas are also generally more severe. Minor modifications in design criteria are, therefore, appropriate for urban streets. ***Chapter 19 – Traditional Neighborhood Development*** provides additional information for the design of urban streets.

#### B.2.b.2 Major/Minor

Streets and highways may be classified as major or minor depending upon traffic volume, trip length, and mobility.

Additional information on the functional classification of roadways may be found in ***Highway Functional Classification Concepts, Criteria and Procedures, 2013 Edition (FHWA)***.

# C CONSIDERATIONS FOR ROADSIDE DESIGN

The following criteria should be considered and resolved in the initial planning and design of streets and highways. The criteria are not listed in order of priority, and the weighting of each criterion should be based on the context of a project, the available resources, and the users.

## C.1 Safety

Development of safe streets and highways for all modes of surface transportation (autos, trucks, bicycles, pedestrians, transit vehicles, etc.) should be given a high priority in the design process. Good roadway design is key to safe and efficient operation and should be sensitive to the surrounding environment. The safety performance of roadway elements should be considered in planning, design, construction, maintenance, and operation phases to be truly comprehensive.

## C.2 Economic Constraints

In determining the benefit/cost ratio for any proposed facility, the economic evaluation should go beyond the actual expenditure of highway funds and the capacity and efficiency of the facility. Overall costs and benefits of various alternatives should include an evaluation of all known environmental, community, and social impacts; and their effect upon highway quality and cost.

Allocation of sufficient funds for obtaining the proper corridor and adequate right of way and alignment should receive the initial priority. Future acquisition of additional right of way and major changes in alignment are often economically prohibitive. This can result in substandard streets and highways with permanent hazards. Reconstruction or modification under traffic is expensive, inconvenient, and hazardous to the highway user. This increase in costs, hazards, and inconvenience can be limited by initial development of quality facilities.

## C.3 Access

Although the public must have reasonable access to the highway network, it is necessary to have certain controls and restrictions. Allowing indiscriminate access can seriously compromise the safety capacity and level of service of a street or highway, consequently reducing its utility and general economic value. The level and type of access should be tied to the functional class of the roadway.

The proper layout of the highway network and the utilization of effective land use controls (***Chapter 2 - Land Development***) can provide the basis for regulating access. The actual access controls should conform to the guidelines given in ***Chapter 3 - Geometric Design***.

## C.4 Maintenance Capabilities

Planning and design of streets and highways should include provisions for the performance of required maintenance. The planning of the expected maintenance program should be coordinated with the initial highway design to ensure maintenance activities may be conducted without excessive traffic conflicts or hazards.

## C.5 Utility and Transit Operations

Utility accommodation within rights of way is generally considered to be in the public's best interest, since rights of way frequently offer the most practical engineering, construction, and maintenance solutions for utility service to businesses and residences. Utility and transit facility locations should be carefully chosen to optimize operations and safety of the transportation facility. Additional information on the design of transit facilities can be found in ***Chapter 13 – Public Transit***.

## C.6 Emergency Response

Development of an effective emergency response program is dependent upon the nature of the highway network and the effectiveness of the operation of the system. Provisions for emergency access and communication should be considered in the initial planning and design of all streets and highways. Local emergency response personnel should be included in primary activities.

## C.7 Environmental Impact

Construction and operation of streets and highways frequently produces an adverse effect upon the environment. Early consideration and resolution of environmental issues can avoid costly delays and modifications that may compromise the quality and efficiency of operation. Specific topics often encountered include the following:

- Air Quality
- Coastal Zone Resources
- Farmland
- Floodplains
- Hazardous Waste and Brownfields
- Noise
- Roadside Vegetation
- Safe Drinking Water Act
- Water Quality
- Watersheds Management
- Wetlands
- Wild and Scenic Rivers and Wilderness Areas
- Wildlife and Threatened and Endangered Species
- Wildlife, Habitat and Ecosystems

## C.8 Community and Social Impact

Quality and value of a community is directly influenced by the layout and design of streets and highways. Quality of the network determines the freedom and efficiency of movement. Inadequate design of the network and poor land use practices can lead to undesirable community separation and deterioration. Specific design of streets and highways has a large effect upon the overall aesthetic value which is important to the motorist and resident. When using federal funds for transportation projects, the following considerations should be addressed:

- Corridor Preservation
- Historical and Archaeological Preservation
- Scenic Byways
- Section 4(f) and 5(f) if federally funded
- Visual Impacts

### C.9 Modes of Transportation

Planning processes should analyze/evaluate other modes of transportation, including walking and cycling and their relationship to the highway system. Recommendations for incorporation into the design process should be made. This will involve coordination with local, city, county, special interest groups, etc., in developing such recommendations.

## D OPERATION

The concept of operating the existing highway network as a system is essential to promote safety, efficiency, mobility, and economy. This requires comprehensive planning and coordination of all activities on each street and highway. These activities would include maintenance, construction, utility operations, public transit operations, traffic control, and emergency response operations. The behavior of traffic should be considered as an integral part of the operation of streets and highways. Coordination of the planning and supervision of each activity on each facility is necessary to achieve safety and efficient operation of the total highway system.

### D.1 Policy

Each highway agency with general responsibility for existing streets and highways should establish and maintain an operations department. Each existing street or highway should be assigned to the jurisdiction of the operations department. The operations department shall be responsible for planning, supervising, and coordinating all activities affecting the operating characteristics of the highway system under its jurisdiction.

### D.2 Objectives

The primary objective of an operations department shall be to maintain or improve the operating characteristics of the highway system under its jurisdiction. These characteristics include safety, capacity, and level of service. The preservation of the function of each facility, which would include access control, is necessary to maintain these characteristics and the overall general value of a street or highway.

## D.3 Activities

The achievement of these objectives requires the performance of a variety of coordinated activities by the operations department. The following activities should be considered as minimal for promoting the safe and efficient operation of a highway system.

### D.3.a Maintenance and Reconstruction

Maintaining or upgrading the quality of existing facilities is an essential factor in preserving desirable operating characteristics. The planning and execution of maintenance and reconstruction activity on existing facilities must be closely coordinated with all other operational activities and, therefore, should be under the general supervision of the operations department.

All maintenance work should be conducted in accordance with the requirements of ***Chapter 10 - Maintenance***. The priorities and procedures utilized should be directed toward improvement of the existing system. The standards set forth in this Manual should be used as guidelines for establishing maintenance and reconstruction objectives. All maintenance and reconstruction projects should be planned to minimize traffic control conflicts and hazards.

### D.3.b Work Zone Safety

An important responsibility of the operations department is the promotion of work zone safety on the existing highway system. The planning and execution of maintenance, construction, and other activities shall include provisions for the safety of motorists, bicyclists, pedestrians, and workers. All work shall be conducted in accordance with the requirements presented in ***Chapter 11 - Work Zone Safety***.

### D.3.c Traffic Control

Traffic engineering is a vital component of highway operations. The planning and design of traffic control devices should be carried out in conjunction with the overall design of the street or highway and highway user. The devices and procedures utilized for traffic control should be predicated upon developing uniformity throughout the system and compatibility with adjacent jurisdictions.

A primary objective to be followed in establishing traffic control procedures is the promotion of safe, orderly traffic flow. The cooperation of police agencies and coordination with local transit providers is essential for the achievement of this objective. Traffic control during maintenance, construction, utility, or emergency response operations should receive special consideration.

### D.3.d Emergency Response

The emergency response activities (i.e., emergency maintenance and traffic control) of the operations department should be closely coordinated with the work of police, fire, ambulance, medical, and other emergency response agencies. The provisions for emergency access and communications should be included in the initial planning for these activities.

### D.3.e Coordination and Supervision

Coordination and supervision of activities on the highway system should include the following:

- Supervision and/or coordination of all activities of the operations department and other agencies to promote safe and efficient operation
- Coordination of all activities to provide consistency within a given jurisdiction
- Coordination with adjacent jurisdictions to develop compatible highway systems
- Coordination with other transportation modes to promote overall transportation efficiency

### D.3.f Inspection and Evaluation

The actual operation of streets and highways provides valuable experience and information regarding the effectiveness of various activities. Each operations department should maintain a complete inventory of its highway system and continuously inspect and evaluate the priorities, procedures, and techniques utilized in all activities on the existing system under its jurisdiction. Activities by other agencies, as well as any highway agency, should be subjected to this supervision.

Promotion of highway safety should be aided by including a safety office (or officer) as an integral part of the operations department. Functions of this office would include the identification and inventory of hazardous locations and procedures for improving the safety characteristics of highway operations.

Results of this inspection and evaluation program should be utilized to make the modification necessary to promote safe and efficient operation. Feedback for modifying design criteria should be generated by this program. Experience and data obtained from operating the system should be utilized as a basis for recommending regulatory changes. Cooperation of legislative, law enforcement, and regulatory agencies is essential to develop the regulation of vehicles, driver behavior, utility, emergency response activities, and the access land use practices necessary for the safe and efficient operation of the highway system.

## E REFERENCES

Design criteria are established for transportation projects to ensure that they provide safe, economical, and fully-functional multimodal transportation facilities. Various FDOT publications contain information on procedures, criteria, and standards for guiding and controlling design and construction activities. There are many local, state, and federal laws and rules that may impact the design of a project. These laws and rules are referenced in the publications when the Department is aware of them.

For situations where specific design standards or criteria cannot be found in the FDOT publications, current approved technical publications such as ***AASHTO's Policy on Geometric Design of Highways and Streets (2011)*** should be used as design guidelines. Local agencies must ensure that project designs meet or exceed the referenced design criteria and that the standards developed from acceptable guidelines are appropriate for the proposed facility.

The following publications provide further information and guidance for Roadway and Bridge/Structure designs:

- Plans Preparation Manual, Volume I (Topic No. 625-000-007) and Volume II (Topic No. 625-000-008)
  http://www.dot.state.fl.us/rddesign/PPMManual/PPM.shtm

- Design Standards (Standard Indexes) (Topic No. 625-010-003)
  http://www.dot.state.fl.us/rddesign/DesignStandards/Standards.shtm

- A Policy on Geometric Design of Highways and Streets, 6th Edition (AASHTO Green Book) (AASHTO Bookstore GDHS-6)
  https://bookstore.transportation.org/collection_detail.aspx?ID=110

- FDOT Standard Specifications for Road and Bridge Construction
  http://www.dot.state.fl.us/programmanagement/default.shtm

- AASHTO LRFD Bridge Design Specifications, Customary U.S. Units, 7$^{th}$ Edition, (2014) with Interim Revisions (2015 and 2016)
  https://bookstore.transportation.org/

- FDOT Structures Manual (Topic No. 625-020-018)
  http://www.dot.state.fl.us/structures/StructuresManual/CurrentRelease/StructuresManual.shtm

- Florida Intersection Design Guide
  http://www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG.shtm

- NCHRP Report 672 – Roundabouts: An Informational Guide, 2nd Edition
  http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf

- AASHTO Highway Safety Manual, 1st Edition (AASHTO Bookstore HSM-1)
  http://www.highwaysafetymanual.org/Pages/default.aspx

- Local Agency Program Manual (Topic No. 525-010-300)
  http://www.dot.state.fl.us/programmanagement/LP/Default.shtm

- Project Development and Environmental Manual Part 1 and Part 2 (Topic No. 650-000-001)
  http://www.dot.state.fl.us/emo/pubs/pdeman/pdeman1.shtm

- Rigid Pavement Design Manual (Topic No. 625-010-006)
  http://www.dot.state.fl.us/rddesign/PM/Publications.shtm

- Flexible Pavement Design Manual (Topic No. 625-010-002)
  http://www.dot.state.fl.us/rddesign/PM/publicationS.shtm

- FDOT Drainage Manual (Topic No. 625-040-002)
  http://www.dot.state.fl.us/rddesign/Drainage/default.shtm

- Soils and Foundations Handbook
  http://www.dot.state.fl.us/structures/DocsandPubs.shtm

- Standard Highway Signs (FHWA)
  http://mutcd.fhwa.dot.gov/ser-shs_millennium.htm

- Manual on Uniform Traffic Control Devices for Streets and Highways (2009 Edition with Revision Numbers 1 and 2, May 2012)
  http://mutcd.fhwa.dot.gov/kno_2009r1r2.htm

- Roadway Lighting Design Guide (AASHTO Bookstore GL-6)
  https://bookstore.transportation.org/item_details.aspx?id=320

- AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 1st Edition (2015) with 2017 Interims
  https://bookstore.transportation.org/

- Highway Functional Classification: Concepts, Criteria and Procedures, 2013 Edition (FHWA)
  http://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/section00.cfm

- Highway Capacity Manual 2010 (Transportation Research Board) (TRB Bookstore HCM10)
  http://www.trb.org/Main/Blurbs/164718.aspx

- Quality/Level of Service Handbook
  http://www.dot.state.fl.us/planning/systems/programs/sm/los/default.shtm

- Manual on Uniform Traffic Studies (Topic No. 750-020-007)
  http://www.dot.state.fl.us/trafficoperations/

- Surveying Procedure (Topic No. 550-030-101)
  http://www.dot.state.fl.us/surveyingandmapping/doc_pubs.shtm

- Right of Way Mapping Procedure (Topic No. 550-030-015)
  http://www.dot.state.fl.us/surveyingandmapping/doc_pubs.shtm

- Guide for the Development of Bicycle Facilities, 4th Edition (AASHTO Bookstore GBF-4)
  https://bookstore.transportation.org/collection_detail.aspx?ID=116

- Guide for the Planning, Design, and Operation of Pedestrian Facilities, 1st Edition (AASHTO Bookstore GPF-1)
  https://bookstore.transportation.org/

- Accessing Transit Design Handbook for Florida Bus Passenger Facilities
  http://www.dot.state.fl.us/transit/Pages/NewTransitFacilitiesDesign.shtm

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# CHAPTER 2

# LAND DEVELOPMENT

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# CHAPTER 2

# LAND DEVELOPMENT

## A INTRODUCTION

A major portion of street and highway construction and reconstruction is generated by, and is accomplished as a result of, land development for residential, commercial, industrial, and public uses. The general land use layout influences, and is controlled by, connections to adjacent road networks with different transportation modes. Techniques, principles, and general layout used for any development also dictate the resulting internal road network. The arrangement and space allocations for this network may determine whether safe, efficient, and economical streets and highways are constructed or reconstructed.

Some land development practices do not promote the creation of a high quality road network. Poor development layouts often result in streets and highways with bad alignment, insufficient sight distance, and inadequate cross section. Insufficient space allocations result in cramped, hazardous intersections, narrow roadside clear zones, and inadequate room for future modifications and expansions. Failure to provide reasonable control of access causes hazardous operating conditions and a dramatic reduction in the capacity and economic value of streets and highways.

Although there are many conflicting demands in land development, the provision of an adequate road network is essential in preserving the social and economic value of any area. Development controls are needed to aid in the establishment of safe streets and highways that will retain their efficiency and economic worth. Provisions for adequate alignment, right of way, setbacks, expansion, and access control are essential.

It is recognized there are many legal, social, and economic problems involved in land use controls. Proper coordination among the public, various governmental bodies, and public transit and highway agencies should, however, allow for the solution of many problems. Implementation of responsible land use and development regulations along with intergovernmental respect for the goals and objectives of each, will promote a superior, long term transportation network.

## B OBJECTIVES

Provisions for vehicular and pedestrian safety are important objectives to be considered in land development. Other land development objectives, related to surface transportation, should include the promotion of smooth traffic flow, efficiency, economy, aesthetics, and environmental compatibility of the transportation network.

General objectives for land development that should be followed to promote good highway design include the following:

- Preserve the function of each street and highway (i.e., use of arterial and collector streets for local circulation seriously compromises safety and capacity)
- Provide for smooth, logical, and energy efficient traffic types and flow patterns
- Provide for the appropriate vehicular speed
- Reduce traffic conflicts to a minimum and eliminate confusion
- Allow for the application of safe geometric design principles
- Provide for bicycle and pedestrian safety
- Provide for future modifications and expansion
- Provide for aesthetic and environmental compatibility
- Develop economic design, construction, and maintenance strategies
- Provide for appropriate public transit facilities
- Provide accessibility for disabled individuals

# C PRINCIPLES AND GUIDELINES

There are many variables involved in land development; therefore, specific standards and requirements for land use and road network layouts cannot always be applied. Use of sound principles and guidelines can, however, aid in meeting the objectives of a better road network. Proper planning and design of the development layout are necessary to provide a satisfactory road network and to allow for the construction of safe roadways. The following principles and guidelines should be utilized in the design of the road network, in the control of access, and in the land use controls and space allocation that would affect vehicular and pedestrian use.

## C.1 Network Design

The general layout of the road network establishes the traffic flow patterns and conflicts, thereby determining the basic safety and efficiency criteria. The design of the road network should be based on the following principles:

- The layout of street and highway systems should be logical and easily understood by the user.
- The design and layout of all streets and highways should clearly indicate their function (arterial, collector, etc.).
- Local circulation patterns should be compatible with adjacent areas. Arterials and collectors should not be interrupted or substantially altered at development or jurisdictional boundary lines.
- Flow patterns should be designed to interconnect neighborhoods while discouraging through motorized traffic on local street networks.
- Elements in the local circulation should be adequate to avoid the need for extensive traffic controls.
- Often there are streets where abuse of posted speed limits becomes an enforcement problem and can have a negative safety impact on the circulation within an urban or residential network. In other situations, there are community concerns with controlling speed levels such as in areas of concentrated pedestrian activities, those with narrow right of way, areas with numerous access points, on street parking, and other similar concerns. Local authorities may elect to use traffic calming design features which are presented in ***Chapter 15 - Traffic Calming***.

- The internal circulation should be sufficient to provide reasonable travel distance for local trips.

- The road network should be compatible with other transportation modes such as mass transit and pedestrian and bicycle facilities. Conflicts between different modes (particularly with pedestrian and bicycle traffic) should be kept to a minimum.

- The road network layout should be designed to reduce internal traffic and pedestrian conflicts and eliminate confusion. Particular emphasis should be directed toward eliminating substantial speed differentials and hazardous turning and crossing maneuvers. The following principles should be utilized for conflict reduction:

  - Generally the number of intersections should be kept to a minimum but should meet land use needs and flow requirements.

  - Local one-way streets are an option to consider where feasible.

  - Local streets should be designed to limit vehicle speeds (length, width, alignment, and intersections).

  - The network should be designed to reduce the number of crossings and left turn maneuvers that are required.

## C.2 Access Control

The standards and requirements presented in ***Chapter 3 - Geometric Design***, are absolutely necessary to maintain safe and efficient streets and highways. Failure to provide adequate control of access has seriously damaged many existing roadways. Unrestricted access to major collectors and arterials has dramatically reduced their capacity and general economic value. The safety characteristics of these facilities have similarly been diminished by significantly increasing the number of vehicular, pedestrian, and bicycle traffic conflicts.

The utilization of proper control over access is one of the most effective and economical means for maintaining the safety and utility of streets and highways. The procedures and controls used for land development significantly affect access control. The following principles should be utilized in the formation of land use controls for limiting access:

- The standards presented in ***Chapter 3 - Geometric Design, C.8 Access Control***, should provide the basis for establishing land development criteria for control of access.

- The use of an arterial or major collector as an integral part of the internal circulation pattern on private property should be prohibited.

- The intersection of private roads and driveways with arterials or major collectors should be strictly controlled.

- Access to sites which generate major traffic (vehicular, pedestrian, and bicycle), should be located to provide the minimum conflict with other traffic. These generators include schools, shopping centers, business establishments, industrial areas, entertainment facilities, etc.

- Commercial strip development, with the associated proliferation of driveways, should be eliminated. Vehicular and pedestrian interconnections should be encouraged.

- The function of all streets and highways should be preserved by the application of the appropriate access controls.

- The spacing and location of access points should be predicated upon reducing the total traffic and pedestrian conflict.

- Hazardous maneuvers should be restricted by access controls. For example, crossing and left turn maneuvers may be controlled by continuous median separation. Pedestrian access should be allowed at appropriate intervals. Medians with waiting space for pedestrians crossing the street are often necessary.

## C.3 Land Use Controls and Space Allocation

The provisions for adequate space and proper location of various activities is essential to promote safety and efficiency. The following guidelines should be utilized in land use:

- Adequate corridors and space should be considered for utilities. Utility locations should be carefully chosen to minimize interference with the operation of the streets, highways, and sidewalks.

- Adequate space for drainage facilities should be provided. Open drainage facilities should be located well clear of the traveled way.

- Design for pedestrian and bicycle facilities should comply with ***Chapter 8 – Pedestrian Facilities*** and ***Chapter 9 – Bicycle Facilities***.

- Adequate space should be provided for off-street and side-street parking. This is essential in commercial and industrial areas.

- Right of way and setback requirements should be adequate to provide ample sight distance at all intersections.

- Sufficient space should be allocated for the development of adequate intersections, including accessibility for disabled individuals.

- Space allocation for street lighting (existing or planned) should be incorporated into the initial plan. Supports for this lighting should be located outside of the required clear zone unless they are clearly of breakaway type, or are guarded by adequate protective devices. Lighting plans should provide for well-lit, safe waiting and walking areas and shall conform with the provisions of ***Chapter 6 – Lighting***.

- Sufficient right of way should be provided for future widening, modification, or expansion of the highway network.

- Adequate corridors for future freeways, High Occupancy Vehicle (HOV) lanes, arterials, or major collectors should be provided.

- Adequate space for desired or required greenways should be provided.

- Adequate space for appropriate public transit facilities should be provided.

## D CONFLICT AND COORDINATION

There are many demands that tend to conflict with the development of safe and efficient streets and highways. Meeting the demand for access can frequently destroy the capacity of a roadway. Pressure to limit the amount of land dedicated for streets and highways inhibits the construction of an adequate road system. Coordination between highway agencies and other governmental bodies can, however, assist in improving the procedures used in land development. Proper coordination should be solicited from legislative bodies, courts, planning and zoning departments, and transit and other governmental agencies to aid in guaranteeing a well-designed and adequate highway network. Coordination with transit planners, developers, engineers, architects, contractors, and other private individuals, which is also beneficial, should be a continuous process.

# E CONTROL TECHNIQUES

The implementation of a sound highway transportation plan requires certain controls. A logical network design, adequate access controls, and proper land use controls are dependent upon and foster proper land development practices. Techniques that may be utilized to establish these necessary controls include the following:

## E.1 Right of Way Acquisition

The acquisition of sufficient right of way is essential to allow for the construction of adequate streets and highways as specified in ***Chapter 3 - Geometric Design*** and ***Chapter 4 - Roadside Design***. The provision of adequate space for clear roadside, sight distance, drainage facilities, buffer zones, intersections, transit, sidewalks, frontage roads, and future expansion is also necessary to develop and maintain safe streets and highways.

## E.2 Police Power

The regulatory authority of state and local highway agencies (and other related agencies) should be sufficient to implement the necessary land use controls. The following general regulatory requirements and specific areas of control should be considered as minimum:

### E.2.a General Regulatory Requirements

The necessary elements for achieving the following transportation goals should be incorporated into all land use and zoning ordinances:

- General highway transportation plans should be created and implemented.
- Determination and acquisition of transportation corridors for future expansions is essential.
- Development plans clearly showing all street and highway layouts, transit facilities, pedestrian and bicycle facilities, and utility corridors should be required. The execution of these plans should be enforceable.

- Development plans, building permits, and zoning should be reviewed by the appropriate agency.
- A safety check of proposed streets and highways should be a required step in the review and acceptance of all development plans.

#### E.2.b Specific Control

Specific areas of control necessary to develop adequate and efficient roadways include the following:

- Land use control and development regulations
- Control of access
- Driveway design
- Street and highway layouts
- Location of vehicular and pedestrian generators
- Location of transit, pedestrian, and bicycle facilities
- Right of way and setback requirements for sight distances and clear zone
- Provisions for drainage

### E.3 Contracts and Agreements

Where land purchase or regulatory authority is not available or appropriate, the use of contractual arrangements or agreements with individuals can be beneficial. Negotiations with developers, builders, and private individuals should be used, where appropriate, to aid in the implementation of the necessary controls.

## E.4 Education

Education of the public, developers, and governmental bodies can be beneficial in promoting proper land development controls. The need for future planning, access control, and design standards should be clearly and continuously emphasized. Successful solidification of the cooperation of the public and other governmental bodies depends upon clear presentation of the necessity for reasonable land development controls.

# CHAPTER 3

# GEOMETRIC DESIGN

# TABLES

## FIGURES

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# CHAPTER 3

# GEOMETRIC DESIGN

## A INTRODUCTION

Geometric design is defined as the design or proportioning of the visible elements of the street or highway. The geometry of the street or highway is of central importance since it provides the framework for the design of other highway elements. In addition, the geometric design establishes the basic nature and quality of the vehicle path, which has a primary effect upon the overall safety characteristics of the street or highway.

The design of roadway geometry must be conducted in close coordination with other design elements of the street or highway. These other elements include: pavement design, roadway lighting, traffic control devices, transit, drainage, and structural design. The design should consider safe roadside clear zones, pedestrian safety, emergency response, and maintenance capabilities.

The safety characteristics of the design should be given primary consideration. The initial establishment of sufficient right of way and adequate horizontal and vertical alignment is not only essential from a safety standpoint, but also necessary to allow future upgrading and expansion without exorbitant expenditure of highway funds.

The design elements selected should be reasonably uniform but should not be inflexible.

The minimum standards presented in this chapter should not automatically become the standards for geometric design. The designer should consider use of a higher level, when practical, and consider cost-benefits as well as consistency with adjacent facilities. Reconstruction and maintenance of facilities should, where practical, include upgrading to these minimum standards.

In restricted or unusual conditions, it may not be possible to meet the minimum standards. In such cases, the designer shall obtain an exception in accordance with ***Chapter 14 – Design Exceptions*** from the reviewing or permitting organization. However, every effort should be made to obtain the best possible alignment, grade, sight distance, and proper drainage consistent with the terrain, the development, safety, and fund availability. The concept of road users has expanded in recent years creating additional considerations for the designer.

In making decisions on the standards to be applied to a particular project, the designer must also address the needs of pedestrians, bicyclists, elder road and transit users, people with disabilities, freight movement and other users and uses. This is true for both urban and rural facilities.

The design features of urban local streets are governed by practical limitations to a greater extent than those of similar roads in rural areas. The two dominant design controls are: (1) the type and extent of urban development and its limitations on rights of way and (2) zoning or regulatory restrictions. Some streets primarily are land service streets in residential areas. In such cases, the overriding consideration is to foster a safe and pleasing environment. Other streets are land service only in part, and features of traffic and public transit service may be predominant.

The selection of the type and exact design details of a particular street or highway requires considerable study and thought. When specific criteria is not provided in this Manual and reference is made to guidelines and design details given by current American Association of State Highway and Transportation Officials (AASHTO) publications, these guidelines and standards should generally be considered as minimum criteria. For the design of recreational roads, local service roads, and alleys, see ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***, also known as the ***AASHTO Greenbook*** and other publications.

Right of way and pavement width requirements for new construction may be reduced for the paving of certain existing unpaved streets and very low volume rural roads provided all of the conditions listed below are satisfied:

- The road is functionally classified as a local road.
- The 20-year projected ADT is less than or equal to 400 vehicles per day and the design year projected peak hourly volume is 100 vehicles per hour or less. Note: The design year may be any time within a range of the present to 20 years in the future, depending on the nature of the improvement.
- The road has no foreseeable probability of changing to a higher functional classification through changes in land use, extensions to serve new developing land areas, or any other use which would generate daily or hourly traffic volumes greater than those listed above.
- There is no reasonable possibility of acquiring additional right of way without:
- Incurring expenditures of public funds in an amount which would be excessive compared to the public benefits achieved

- Causing substantial damage or disruption to abutting property improvements to a degree that is unacceptable considering the local environment

## B OBJECTIVES

The major objective in geometric design is to establish a vehicle path and environment providing a reasonable margin of safety for the motorist, transit, bicyclist, and pedestrian under the expected operating conditions and speed. It is recognized that Florida's design driver is aging and tourism is our major industry. This gives even more emphasis on simplicity and easily understood geometry. The design of street or highway features should consider the following:

- Provide the most simple geometry attainable, consistent with the physical constraints
- Provide a design that has a reasonable and consistent margin of safety at the expected operating speed
- Provide a design that is safe at night and under adverse weather conditions
- Provide a facility that is adequate for the expected traffic conditions and transit needs
- Allow for reasonable deficiencies in the driver, such as:
    - Periodic inattention
    - Reduced skill and judgment
    - Slow reaction and response
- Provide an environment that minimizes hazards, is as hazard free as practical, and is "forgiving" to a vehicle that has deviated from the travel path or is out of control.

# C DESIGN ELEMENTS

## C.1 Design Speed

Design speed is a selected speed used to determine the various geometric design features of the street or highway. Selection of an appropriate design speed must consider the anticipated operating speed, topography, existing and future adjacent land use, and functional classification. Consideration must also be given to pedestrian and bicycle usage.

Many critical design features such as sight distance and curvature are directly related to, and vary appreciably with, design speed. For this reason, the selected design speed should be consistent with the speeds that drivers are likely to expect on a given street or highway facility. The design speed shall not be less than the expected posted or legal speed limit. Once the design speed is selected, all pertinent highway features should be related to it to obtain a balanced design.

Above minimum design criteria for specific design elements such as flatter curves and longer sight distances should be used where practical, particularly on high speed facilities. On lower speed facilities, use of above minimum values may encourage travel at speeds higher than the design speed.

The design speed utilized should be consistent over a given section of street or highway. Required changes in design speed should be effected in a gradual fashion. When isolated reductions in design speed cannot reasonably be avoided, appropriate speed signs should be posted.

***AASHTO's A Policy on Geometric Design of Highways and Streets (2011)*** may be referenced for a more thorough discussion of design speed.

Recommended values for design speed are provided in Table 3 – 1 Recommended Design Speed. These values should be considered as general guidelines only.

High speed facilities are defined as those facilities with design speeds 50 mph and greater. Low speed facilities are defined as those facilities with design speeds 45 mph and less.

**Table 3 – 1**
**Recommended Design Speed (mph)**

| **Facility[1]** | | **AADT (vpd)** | **Terrain** | **Design Speed (mph)** |
|---|---|---|---|---|
| Freeways | Rural | All | Level and Rolling | 70 |
| | Urban | All | Level and Rolling | 50 – 70[2] |
| Arterials | Rural | All | Level | 60 – 70 |
| | | | Rolling | 50 – 70 |
| | Urban | All | All | 30 – 60[3] |
| Collectors | Rural | ≥ 400 | Level | 60 – 65 (50 mph min for AADT 400 to 2000) |
| | | | Rolling | 50 – 65 (40 mph min for AADT 400 to 2000) |
| | | < 400 | Level | 40 – 60 |
| | | | Rolling | 30 – 60 |
| | Urban | All | All | 30 – 50[3] |
| Local | Rural | ≥ 400 | Level | 50 – 60 |
| | | | Rolling | 40 – 60 |
| | | < 400 | Level | 40 – 60 (30 mph min for AADT < 250) |
| | | | Rolling | 30 – 60 (20 mph min for AADT < 50) |
| | Urban | All | All | 20 – 30[4] |

Table Continued on Next Page:

Footnotes:

1. Urban design speeds are applicable to streets and highways located within designated urban boundaries as well as those streets and highways outside designated urban boundaries yet within small communities or urban like developed areas. Rural design speeds are applicable to all other rural areas.

2. A design speed of 70 mph should be used for urban freeways when practical. Lower design speeds should only be used in highly developed areas with closely spaced interchanges. For these areas a minimum design speed of 60 mph is recommended unless it can be shown lower speeds will be consistent with driver expectancy.

3. Lower speeds apply to central business districts and in more developed areas while higher speeds are more applicable to outlying and developing areas.

4. Since the function of urban local streets is to provide access to adjacent property, all design elements should be consistent with the character of activity on and adjacent to the street, and should encourage speeds generally not exceeding 30 mph.

## C.2 Design Vehicles

A "design vehicle" is a vehicle with representative weight, dimensions, and operating characteristics, used to establish street and highway design controls for accommodating vehicles of designated classes. For the purpose of geometric design, the design vehicle should be one with dimensions and minimum turning radii larger than those of almost all vehicles in its class. Design vehicles are listed in Table 3 – 2 Design Vehicles*.* One or more of these vehicles should be used as a control in the selection of geometric design elements. In certain industrial (or other) areas, special service vehicles may have to be considered in the design. Fire equipment and emergency vehicles should have reasonable access to all areas.

If a significant number or percentage (5 percent of all the total traffic) of vehicles of those classes larger than passenger vehicles are likely to use a particular street or highway, that class should be used as a design control. The design of arterial streets and highways should normally be adequate to accommodate all design vehicles. The decision as to which of the design vehicles (or other special vehicles) should be used as a control is complex and requires careful study. Each situation must be evaluated individually to arrive at a reasonable estimate of the type and volume of expected traffic.

- Design criteria significantly affected by the type of vehicle include:
- Horizontal and vertical clearances
- Alignment
- Lane widening on curves
- Shoulder width requirements
- Turning roadway and intersection radii
- Intersection sight distance
- Acceleration criteria

Particular care should be taken in establishing the radii at intersections, so vehicles may enter the street or highway without encroaching on adjacent travel lanes or leaving the pavement. It is acceptable for occasional trucks or buses to make use of both receiving lanes, especially on side streets.

**Table 3 – 2**
**Design Vehicles**

| DESIGN VEHICLE | | DIMENSIONS IN FEET | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type | Symbol | Wheelbase | Overhang | | Overall Length | Overall Width | Height |
| | | | Front | Rear | | | |
| Passenger Car | P | 11 | 3 | 5 | 19 | 7 | 4.3 |
| Single Unit Truck | SU-30 | 20 | 4 | 6 | 30 | 8 | 11-13.5 |
| Single Unit Truck – 3 Axle | SU-40 | 25 | 4 | 10.5 | 39.5 | 8 | 11-13.5 |
| City Transit Bus | CITY-BUS | 25 | 7 | 8 | 40 | 8.5 | 10.5 |
| Conventional School Bus (65 passenger) | S-BUS 36 | 21.3 | 2.5 | 12.0 | 35.8 | 8.0 | 10.5 |
| Articulated Bus | A-BUS | 22+19.4=41.4 | 8.6 | 10 | 60 | 8.5 | 11 |
| Motor Home | MH | 20 | 4 | 6 | 30 | 8 | 12 |
| Car & Camper Trailer | P/T | 11+5+17.7=33.7** | 3 | 12 | 48.7 | 8 | 10 |
| Car & Boat Trailer | P/B | 11+5+15=31** | 3 | 8 | 42 | 8 | --- |
| Intermediate Semitrailer | WB-40 | 12.5+25.5=38 | 3 | 4.5 | 45.5 | 8 | 13.5 |
| Intermediate Semitrailer | WB-50 | 14.6+35.4=50 | 3 | 2 | 55 | 8.5 | 13.5 |
| Interstate Semitrailer | WB-62 | 19.5+41=60.5 | 4 | 4.5 | 69 | 8.5 | 13.5 |
| Florida Interstate Semitrailer | WB-62FL | 19.5+41=60.5 | 4 | 9 | 73.5 | 8.5 | 13.5 |
| Interstate Semitrailer | WB-67 | 21.6+45.4=67 | 4 | 2.5 | 73.5 | 8.5 | 13.5 |
| "Double-Bottom"-Semitrailer/Trailer Combination | WB-67D | 11+23+10*+22.5=66.5 | 2.3 | 3.0 | 72.3 | 8.5 | 13.5 |

Source: 2011 AASHTO Greenbook, Design Controls and Criteria, Table 2-1b.

* Distance between rear wheels of front trailer and front wheels of rear trailer
** Distance between rear wheels of trailer and front wheels of car

## C.3 Sight Distance

The provision for adequate horizontal and vertical sight distance is an essential factor in the development of a safe street or highway. An unobstructed view of the upcoming roadway is necessary to allow time and space for the safe execution of passing, stopping, intersection movements, and other normal and emergency maneuvers. It is also important to provide as great a sight distance as possible to allow the driver time to plan for future actions. The driver is continuously required to execute normal slowing, turning, and acceleration maneuvers. If he can plan in advance for these actions, traffic flow will be smoother and less hazardous. Unexpected emergency maneuvers will also be less hazardous if they are not combined with uncertainty regarding the required normal maneuvers. The appropriate use of lighting (***Chapter 6 – Lighting***) may be required to provide adequate sight distances for night driving.

Future obstruction to sight distance that may develop (e.g., vegetation) or be constructed should be taken into consideration in the initial design. Areas outside of the road right of way that are not under the highway agency's jurisdiction should be considered as points of obstruction. Planned future construction of median barriers, guardrails, grade separations, or other structures should also be considered as possible sight obstructions.

### C.3.a Stopping Sight Distance

Safe stopping sight distances shall be provided continuously on all streets and highways. The factors, which determine the minimum distance required to stop, include:

- Vehicle speed
- Driver's total reaction time
- Characteristics and conditions of the vehicle
- Friction capabilities between the tires and the roadway surface
- Vertical and horizontal alignment of the roadway

It is desirable that the driver be given sufficient sight distance to avoid an object or slow moving vehicle with a natural, smooth maneuver rather than an extreme or panic reaction.

The determination of available stopping sight distance shall be based on a height of the driver's eye equal to 3.50 feet and a height of obstruction to be avoided equal to two feet (2.0 feet). It would, of course, be desirable to use a height of obstruction equal to zero (coincident with the roadway surface) to provide the driver with a more positive sight condition. Where horizontal sight distance may be obstructed on curves, the driver's eye and the obstruction shall be assumed to be located at the centerline of the traffic lane on the inside of the curve.

The stopping sight distance shall be no less than the values given in Table 3 – 3 Stopping Sight Distances.

**Table 3 – 3**
**Stopping Sight Distances**

| MINIMUM STOPPING SIGHT DISTANCES (feet)<br>(For application of stopping sight distance, use an eye height of 3.50 feet and an object height of 2 feet above the road surface) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Speed (mph) | | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| Stopping Sight Distance (feet) | | 115 | 155 | 200 | 250 | 305 | 360 | 425 | 495 | 570 | 645 | 730 |

Source: 2011 AASHTO Greenbook, Table 3-1.

### C.3.b Passing Sight Distance

The passing maneuver, which requires occupation of the opposing travel lane, is inherently dangerous. The driver is required to make simultaneous estimates of time, distance, relative speeds, and vehicle capabilities. Errors in these estimates result in frequent and serious crashes.

Streets or highways with two or more travel lanes in a given direction are not subject to requirements for safe passing sight distance. Two-lane, two-way highways should be provided with safe passing sight distance for as much of the highway as feasible. The driver demand for passing opportunity is high and serious limitations on the opportunity for passing reduces the capacity and safe characteristics of the highway.

The distance traveled after the driver's final decision to pass (while encroaching into the opposite travel path) is that which is required to pass and return to the original travel lane in front of the overtaken vehicle. In addition to this distance, the safe passing sight distance must include the distance traveled by an opposing vehicle during this time period, as well as a reasonable margin of safety. Due to the many variables in vehicle characteristics and driver behavior, the passing sight distance should be as long as is practicable.

The determination of passing sight distance shall be based on a height of eye equal to 3.50 feet and a height of object passing equal to 3.50 feet. Where passing is permitted, the passing sight distance shall be no less than the values given in Table 3 – 4 Passing Sight Distances.

**Table 3 – 4**
**Passing Sight Distances**

| MINIMUM PASSING SIGHT DISTANCES (feet)<br>(For application of passing sight distance, use an eye height of 3.50 feet and an object height of 3.50 feet above the road surface) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Speed (mph) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| Minimum Passing Sight Distance (feet) | 400 | 450 | 500 | 550 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 |

Source: 2011 AASHTO Greenbook, Table 3-4.

### C.3.c Sight Distance at Decision Points

It is desirable to provide sight distances exceeding the minimum at changes in geometry, approaches to intersections, entrances and exits, and other potential decision points or hazards. The sight distance should be adequate to allow the driver sufficient time to observe the upcoming situation, make the proper decision, and take the appropriate action in a normal manner.

Minimum stopping distance does not provide sufficient space or time for the driver to make decisions regarding complex situations requiring more than simple perception-reaction process. In many cases, rapid stopping or lane changing may be extremely undesirable and cause hazardous maneuvers (i.e., in heavy traffic conditions); therefore, it would be preferable to provide sufficient sight distance to allow for a more gradual reaction.

The sight distance on a freeway preceding the approach nose of an exit ramp should exceed the minimum by 25 percent or more. A minimum sight distance of 1000 feet, measured from the driver's eye to the road surface is a desirable goal. There should be a clear view of the exit terminal including the exit nose.

#### C.3.d Intersection Sight Distance

Sight distances for intersection movements are given in the general intersection requirements (C.9 Intersection Design, this chapter).

### C.4 Horizontal Alignment

#### C.4.a General Criteria

The standard of alignment selected for a particular section of street or highway should extend throughout the section with no sudden changes from easy to sharp curvature. Where sharper curvature is unavoidable, a sequence of curves of increasing degree should be utilized.

Winding alignment consisting of sharp curves is hazardous, reduces capacity, and should be avoided. The use of as flat a curve as possible is recommended. Flatter curves are not only less hazardous, but also frequently less costly due to the shortened roadway.

Maximum curvature should not be used in the following locations:

- High fills or elevated structures. The lack of surrounding objects reduces the driver's perception of the roadway alignment.
- At or near a crest in grade
- At or near a low point in a sag or grade
- At the end of long tangents
- At or near intersections, transit stops, or points of ingress or egress
- At or near other decision points

The "broken back" arrangement of curves (short tangent between two curves in the same direction) should be avoided. This is acceptable only at design speeds of 30 mph or less. This arrangement produces an unexpected and hazardous situation.

When reversals in alignment are used and superelevation is required, a sufficient length of tangent between the reverse curves is required for adequate superelevation transition.

Compound curves should be avoided, especially when curves are sharp. They tend to produce erratic and dangerous vehicle operations. When compound curves are necessary, the radius of the flatter curve should not be more than 50 percent greater than the sharper curve.

The transition between tangents and curves should normally be accomplished by the use of appropriate straight-line transitions or spirals. This is essential to assist the driver in maintaining his vehicle in the proper travel path.

For small deflection angles, curves should be suitably lengthened to avoid the distracting appearance of a kink. Curves should be at least 900 feet long for a central angle of 1 degree or 500 feet long for a central angle of 5 degrees. Gently flowing alignment is generally more pleasing in appearance, as well as, superior from a safety standpoint.

### C.4.b Superelevation

In the design of street and highway curves, it is necessary to establish a proper relationship between curvature of the roadway and design speed. The use of superelevation (rotation of the roadway about its axis) is employed to counteract centrifugal force and allow drivers to comfortably and safely travel through curves at the design speed.

The superelevation rates for rural highways, urban freeways, and high speed urban highways are shown in Figure 3 – 1 Rural Highways, Urban Freeways and High Speed Urban Highways. These rates are based on a maximum rate of 0.10 foot per foot of roadway width. Additional superelevation details, given in the Department's Design Standards, may be considered.

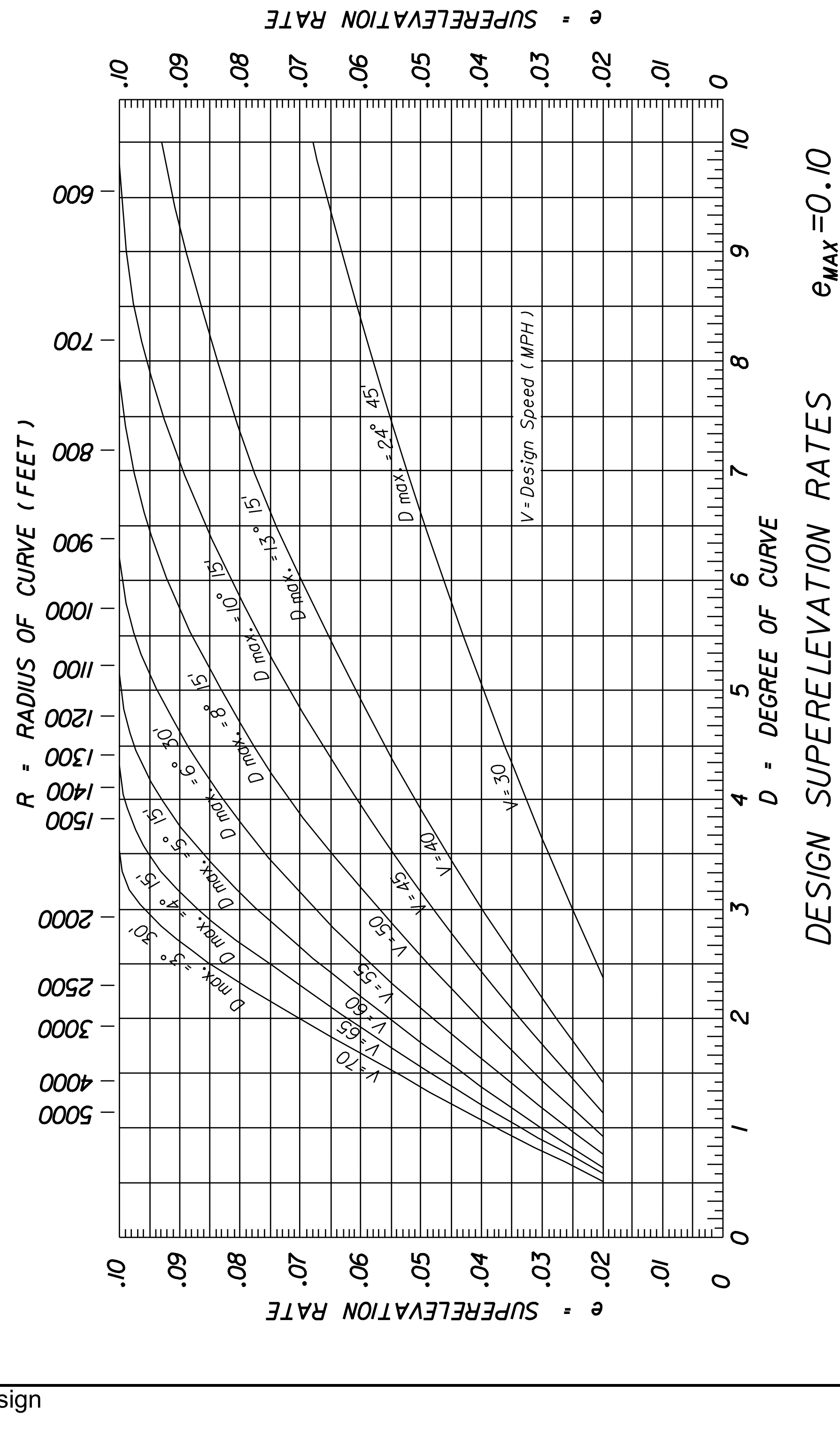
The superelevation rates recommended for urban highways and high speed urban streets are shown in Figure 3 – 2 Superelevation Rates (e) For Urban Highways and High Speed Urban Streets. These rates are based on a maximum superelevation rate of 0.05 foot per foot and are recommended for arterials and collectors in built up areas. Additional information regarding superelevation, given in the Department's Design Standards, and ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***, may be considered.

Although superelevation is advantageous for traffic operations, various factors combine to make its use impractical in many built-up areas. Such factors include:

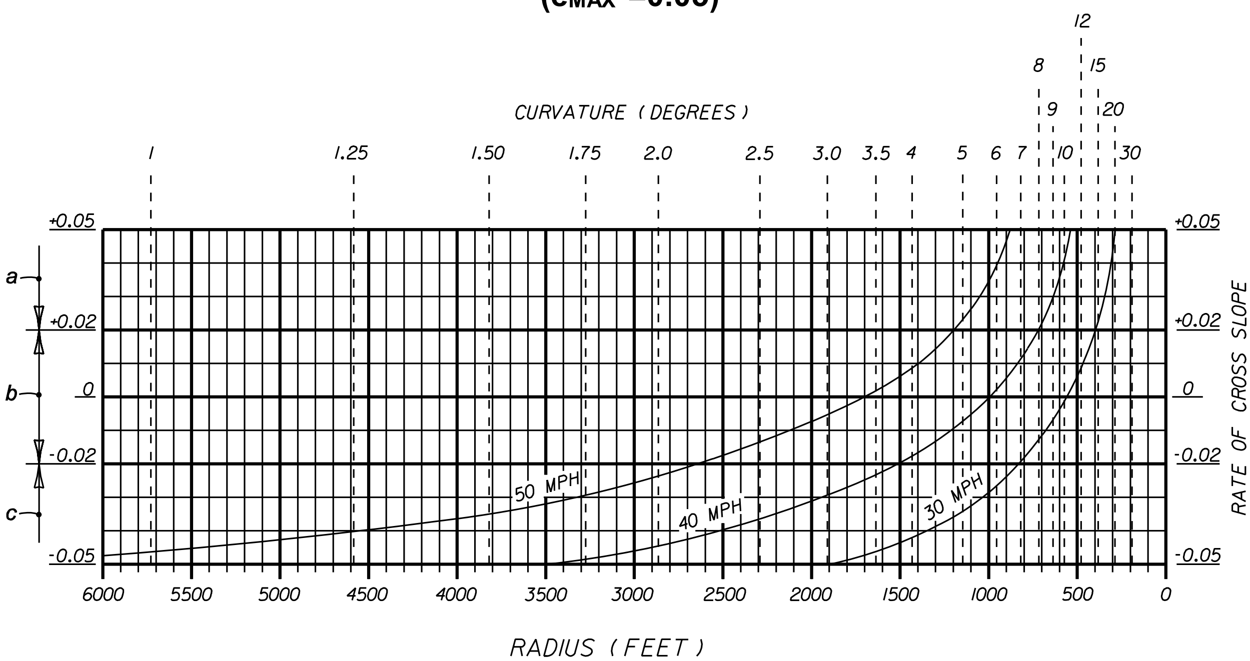
- Wide pavement areas
- Need to meet grade of adjacent property
- Surface drainage considerations
- Frequency of cross streets, alleys, and driveways

Therefore, horizontal curves on lower speed streets in residential and urban areas are usually designed without superelevation, only side friction being used to counteract the centrifugal force. Figure 3 – 3 Maximum Safe Speed for Horizontal Curves Urban-Lower Speed Streets may be used for determination of the maximum safe speed for horizontal curves on lower speed urban streets.

# Figure 3 – 1
## Rural Highways, Urban Freeways and High Speed Urban Highways



## Figure 3 – 2
## Superelevation Rates (e) For Urban Highways and High Speed Urban Streets
## ($e_{MAX}$ =0.05)

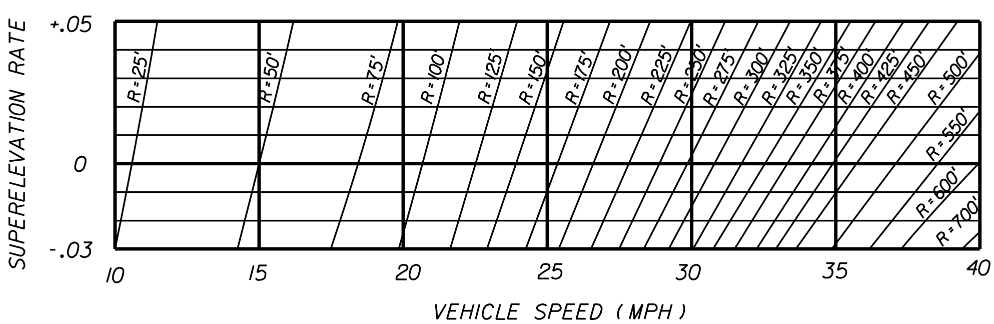



a. When the speed curves and the degree of curve lines intersect above this line, the pavement is to be superelevated (positive slope) at the rates indicated at the lines intersecting points.

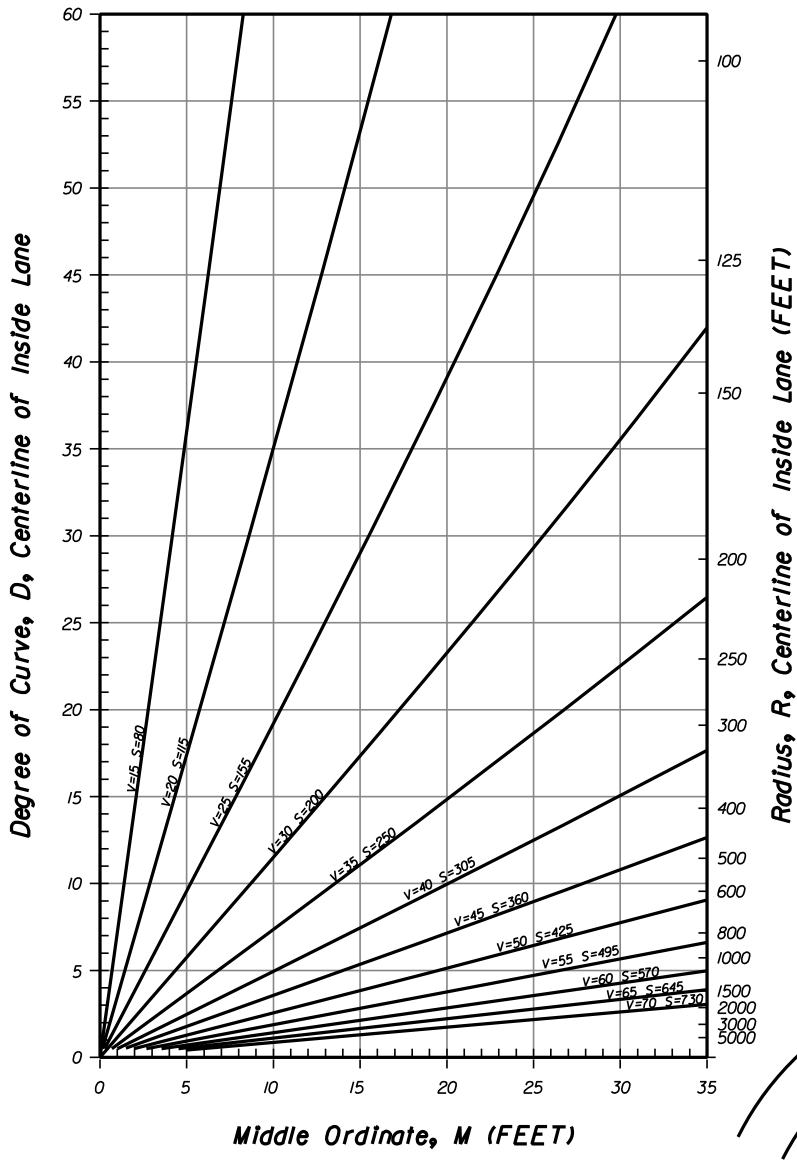
b. When the speed curves and the degree of curve lines intersect between these limits, the pavement is to be superelevated at the rate of 0.02 (positive slope).

c. When the speed curves and the degree of curve lines intersect below this line, the pavement is to have normal crown (typically 0.02 and 0.03 downward slopes).

## Figure 3 – 3 Maximum Safe Speed For Horizontal Curves Urban-Lower Speed Streets



# Figure 3 – 4
## Sight Distance on Curves




$$M = \frac{5730}{D}\left(1 - \text{Cos}\frac{SD}{200}\right)$$

$$R = \frac{5730}{D} \quad \text{and} \quad \theta = \frac{SD}{200}$$

$$M = R\,(1\text{-Cos}\,\theta)$$

$$M = R\left(1\text{-Cos}\ \frac{28.65\ S}{R}\right)$$

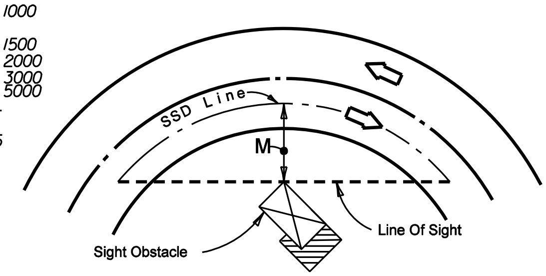
Where

S = Stopping Sight Distance (FEET)

D = Degree of Curve

M = Middle Ordinate (FEET)

R = Radius (FEET)




RELATION BETWEEN DEGREE OF CURVE AND VALUE OF MIDDLE ORDINATE NECESSARY TO PROVIDE STOPPING SIGHT DISTANCE ON HORIZONTAL CURVES UNDER OPEN ROAD CONDITIONS.

### C.4.c Curvature

Where a directional change in alignment is required, every effort should be made to utilize the smallest degree (largest radius) curvature possible. The use of the maximum degree of curvature should be avoided when possible. Design speed maximum degree of curvature relationships are given in Table 3 - 5 Horizontal Curvature. The use of sharper curvature for the design speeds shown in Table 3 - 5 would call for superelevation beyond the limit considered practical or for operation with tire friction beyond safe or comfortable limits or both. The maximum degree of curvature is a significant value in alignment design.

**Table 3 – 5**
**Horizontal Curvature**

| RURAL Based on $e_{MAX}$ = 0.10 | | | URBAN High-Speed Highways and Streets Based on $e_{MAX}$ = 0.05 | | |
|---|---|---|---|---|---|
| Design Speed (mph) | Max. Degree of Curvature | Min. Radius (feet) | Design Speed (mph) | Max. Degree of Curvature | Min. Radius (feet) |
| 20 | 79° 30' | 75 | --- | --- | --- |
| 25 | 45° 15' | 130 | --- | --- | --- |
| 30 | 28° 30' | 200 | 30 | 23° 45' | 245 |
| 35 | 19° 30' | 295 | 35 | 16° 00' | 360 |
| 40 | 13° 45' | 415 | 40 | 11° 15' | 510 |
| 45 | 10° 30' | 540 | 45 | 8° 15' | 680 |
| 50 | 8° 15' | 695 | 50 | 6° 30' | 880 |
| 55 | 6° 30' | 880 | 55 | 5° 00' | 1125 |
| 60 | 5° 15' | 1095 | --- | --- | --- |
| 65 | 4° 15' | 1345 | --- | --- | --- |
| 70 | 3° 30' | 1640 | --- | --- | --- |

| LOW-SPEED URBAN STREETS | | | | |
|---|---|---|---|---|
| Design Speed (mph) | With $e_{MAX}$ = 0.05 | | Without Superelevation ($e_{MAX}$ = -0.02) | |
| | Max. Degree of Curvature | Min. Radius (feet) | Max. Degree of Curvature | Min. Radius (feet) |
| 20 | 68° 45' | 85 | 53° 30' | 110 |
| 25 | 38° 30' | 150 | 28° 45' | 200 |
| 30 | 23° 45' | 240 | 17° 00' | 335 |

**(TABLE CONTINUES ON NEXT PAGE)**

## Table 3 – 5
## Horizontal Curvature
(Continued)

| LATERAL CLEARANCE FROM EDGE OF TRAVELED WAY TO OBSTRUCTION FOR MAXIMUM CURVATURE (DEGREES), BASED ON LINE OF SIGHT ON INSIDE LANE (Lateral Clearance = $M_{Inside\ Lane}$ – 6' ) Based on $e_{MAX}$ = 0.10 | | |
|---|---|---|
| Design Speed (mph) | Maximum Curvature | Clearance (feet) |
| 20 | 79° 30’ | 15 |
| 25 | 45° 15’ | 17 |
| 30 | 28° 30' | 18 |
| 35 | 19° 30' | 20 |
| 40 | 13° 45' | 22 |
| 45 | 10° 30' | 24 |
| 50 | 8° 15' | 27 |
| 55 | 6° 30' | 29 |
| 60 | 5° 15' | 31 |
| 65 | 4° 15' | 33 |
| 70 | 3° 30' | 35 |

### C.4.d Superelevation Transition (superelevation runoffs plus tangent runoff)

Superelevation runoff is the general term denoting the length of street or highway needed to accomplish the change in cross slope from a section with the adverse crown removed (level) fully superelevated section, or vice versa. Tangent runoff is the general term denoting the length of street or highway needed to accomplish the change in cross slope from a normal cross section to a section with the adverse crown removed, or vice versa. Spiral curves can be used to transition from the tangent to the curve. Where the spiral curve is employed, its length is used to make the entire superelevation transition.

The Department's Design Standards show in detail superelevation transitions for various sections and methods for determining length of transition.

### C.4.e Lane Widening on Curves

The traveled way should be widened on sharp curves due to the increased difficulty for the driver to follow the proper path. Trucks and transit vehicles experience additional difficulty due to the fact that the rear wheels may track considerably inside the front wheels thus requiring additional width. Adjustments to traveled way widths for mainline and turning roadways are given in Tables 3 – 6A Calculated and Design Values for Traveled Way Widening on Open Highway Curves (Two-Lane Highways, One-Way or Two-Way and 3 – 6B Adjustments or Traveled Way Widening Values on Open Highway Curves (Two-Lane Highways, One-Way or Two-Way. A transition length shall be introduced in changing to an increased/decreased lane width. This transition length shall be proportional to the increase/decrease in traveled way width in a ratio of not less than 50 feet of transition length for each foot of change in lane width.

## Table 3 – 6A
## Calculated and Design Values for Traveled Way Widening on Open Highway Curves
### (Two-Lane Highways, One-Way or Two-Way)

| Radius of Curve (feet) | Roadway width = 24 feet. | | | | | | | Roadway width = 22 feet. | | | | | | | Roadway width = 20 feet. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Design Speed (mph) | | | | | | | Design Speed (mph) | | | | | | | Design Speed (mph) | | | | | | |
| | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 7000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.9 | 0.9 | 1.6 | 1.6 | 1.7 | 1.7 | 1.8 | 1.9 | 1.9 |
| 6500 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.9 | 1.0 | 1.6 | 1.7 | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 |
| 6000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.7 | 0.8 | 0.8 | 0.9 | 1.0 | 1.0 | 1.6 | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 | 2.0 |
| 5500 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.7 | 0.7 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.7 | 1.7 | 1.8 | 1.9 | 1.9 | 2.0 | 2.1 |
| 5000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.7 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.1 | 1.7 | 1.8 | 1.9 | 1.9 | 2.0 | 2.1 | 2.1 |
| 4500 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.8 | 0.8 | 0.9 | 1.0 | 1.1 | 1.1 | 1.2 | 1.8 | 1.8 | 1.9 | 2.0 | 2.1 | 2.1 | 2.2 |
| 4000 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.3 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.2 | 2.3 |
| 3500 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.3 | 1.4 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 |
| 3000 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
| 2500 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 |
| 2000 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 1.0 | 1.1 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 2.0 | 2.1 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 3.0 | 3.1 |
| 1800 | 0.5 | 0.6 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.5 | 1.6 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.5 | 2.6 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 |
| 1600 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.3 | 1.4 | 1.7 | 1.8 | 1.9 | 2.0 | 2.2 | 2.3 | 2.4 | 2.7 | 2.8 | 2.9 | 3.0 | 3.2 | 3.3 | 3.4 |
| 1400 | 0.8 | 1.0 | 1.1 | 1.2 | 1.4 | 1.5 | 1.6 | 1.8 | 2.0 | 2.1 | 2.2 | 2.4 | 2.5 | 2.6 | 2.8 | 3.0 | 3.1 | 3.2 | 3.4 | 3.5 | 3.6 |
| 1200 | 1.1 | 1.2 | 1.4 | 1.5 | 1.7 | 1.8 | 1.9 | 2.1 | 2.2 | 2.4 | 2.5 | 2.7 | 2.8 | 2.9 | 3.1 | 3.2 | 3.4 | 3.5 | 3.7 | 3.8 | 3.9 |
| 1000 | 1.4 | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.4 | 2.4 | 2.6 | 2.7 | 2.9 | 3.0 | 3.2 | 3.4 | 3.4 | 3.6 | 3.7 | 3.9 | 4.0 | 4.2 | 4.4 |
| 900 | 1.6 | 1.8 | 2.0 | 2.1 | 2.3 | 2.5 | | 2.6 | 2.8 | 3.0 | 3.1 | 3.3 | 3.5 | | 3.6 | 3.8 | 4.0 | 4.1 | 4.3 | 4.5 | |
| 800 | 1.9 | 2.1 | 2.2 | 2.4 | 2.6 | 2.8 | | 2.9 | 3.1 | 3.2 | 3.4 | 3.6 | 3.8 | | 3.9 | 4.1 | 4.2 | 4.4 | 4.6 | 4.8 | |
| 700 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | | | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 | | | 4.2 | 4.4 | 4.6 | 4.8 | 5.0 | | |
| 600 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | | | 3.7 | 3.9 | 4.1 | 4.3 | 4.5 | | | 4.7 | 4.9 | 5.1 | 5.3 | 5.5 | | |
| 500 | 3.3 | 3.5 | 3.7 | 3.9 | | | | 4.3 | 4.5 | 4.7 | 4.9 | | | | 5.3 | 5.5 | 5.7 | 5.9 | | | |
| 450 | 3.7 | 3.9 | 4.1 | | | | | 4.7 | 4.9 | 5.1 | | | | | 5.7 | 5.9 | 6.1 | | | | |
| 400 | 4.2 | 4.4 | 4.7 | | | | | 5.2 | 5.4 | 5.7 | | | | | 6.2 | 6.4 | 6.7 | | | | |
| 350 | 4.8 | 5.1 | 5.3 | | | | | 5.8 | 6.1 | 6.3 | | | | | 6.8 | 7.1 | 7.3 | | | | |
| 300 | 5.6 | 5.9 | | | | | | 6.6 | 6.9 | | | | | | 7.6 | 7.9 | | | | | |
| 250 | 6.8 | | | | | | | 7.8 | | | | | | | 8.8 | | | | | | |
| 200 | 8.5 | | | | | | | 9.5 | | | | | | | 10.5 | | | | | | |

Notes: Values shown are for WB-50 design vehicle and represent widening in feet. For other design vehicles, use adjustments in Table 3-6B.
Values less than 2.0 feet may be disregarded.
For 3-lane roadways, multiply above values by 1.5.
For 4-lane roadways, multiply above values by 2.

**Table 3 – 6B**
**Adjustments for Traveled Way Widening Values on Open Highway Curves**
**(Two-Lane Highways, One-Way or Two-Way)**

| Radius of Curve (feet) | Design Vehicle | | | | | | |
|---|---|---|---|---|---|---|---|
| | SU | WB-40 | WB-62 | WB-65 | WB-67D | WB-100T | WB-109D |
| 7000 | -1.1 | -1.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.3 |
| 6500 | -1.1 | -1.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.3 |
| 6000 | -1.2 | -1.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.3 |
| 5500 | -1.2 | -1.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.4 |
| 5000 | -1.2 | -1.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.4 |
| 4500 | -1.2 | -1.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.5 |
| 4000 | -1.2 | -1.2 | 0.2 | 0.2 | -0.1 | 0.1 | 0.5 |
| 3500 | -1.3 | -1.2 | 0.2 | 0.3 | -0.1 | 0.1 | 0.6 |
| 3000 | -1.3 | -1.2 | 0.2 | 0.3 | -0.1 | 0.1 | 0.7 |
| 2500 | -1.4 | -1.2 | 0.3 | 0.4 | -0.1 | 0.1 | 0.8 |
| 2000 | -1.5 | -1.3 | 0.3 | 0.5 | -0.1 | 0.2 | 1.0 |
| 1800 | -1.5 | -1.3 | 0.4 | 0.5 | -0.1 | 0.2 | 1.1 |
| 1600 | -1.6 | -1.4 | 0.4 | 0.6 | -0.1 | 0.2 | 1.3 |
| 1400 | -1.7 | -1.4 | 0.5 | 0.6 | -0.2 | 0.2 | 1.5 |
| 1200 | -1.8 | -1.5 | 0.5 | 0.8 | -0.2 | 0.3 | 1.7 |
| 1000 | -2.0 | -1.6 | 0.6 | 0.9 | -0.2 | 0.3 | 2.0 |
| 900 | -2.1 | -1.7 | 0.7 | 1.0 | -0.2 | 0.4 | 2.3 |
| 800 | -2.2 | -1.8 | 0.8 | 1.1 | -0.3 | 0.4 | 2.6 |
| 700 | -2.4 | -1.9 | 0.9 | 1.3 | -0.3 | 0.5 | 2.9 |
| 600 | -2.6 | -2.0 | 1.1 | 1.5 | -0.4 | 0.6 | 3.4 |
| 500 | -2.9 | -2.2 | 1.3 | 1.8 | -0.4 | 0.7 | 4.1 |
| 450 | -3.2 | -2.4 | 1.4 | 2.0 | -0.5 | 0.7 | 4.6 |
| 400 | -3.4 | -2.5 | 1.6 | 2.3 | -0.5 | 0.8 | 5.1 |
| 350 | -3.8 | -2.8 | 1.9 | 2.6 | -0.6 | 1.0 | 5.9 |
| 300 | -4.3 | -3.0 | 2.2 | 3.0 | -0.7 | 1.1 | 6.9 |
| 250 | -4.9 | -3.5 | 2.6 | 3.7 | -0.9 | 1.4 | 8.3 |
| 200 | -5.9 | -4.1 | 3.3 | 4.6 | -1.1 | 1.7 | 10.5 |

Notes: Adjustments are applied by adding to or subtracting from the values in Table 3 – 6A
Adjustments depend only on radius and design vehicle; they are independent of traveled way width and design speed.
For 3-lane roadways, multiply above values by 1.5.
For 4-lane roadways, multiply above values by 2.0.

## C.5 Vertical Alignment

### C.5.a General Criteria

The selection of vertical alignment should be predicated to a large extent upon the following criteria:

- Obtaining maximum sight distances
- Limiting speed differences (particularly for trucks and buses) by reducing magnitude and length of grades
- A "hidden dip" which would not be apparent to the driver must be avoided.
- Steep grades and sharp crest vertical curves should be avoided at or near intersections.
- Flat grades and long gentle vertical curves should be used whenever possible.

### C.5.b Grades

The grades selected for vertical alignment should be as flat as practical, and should not be greater than the value given in Table 3 – 7 Recommended Maximum Grades in Percent.

For streets and highways requiring long upgrades, the maximum grade should be reduced so the speed reduction of slow-moving vehicles (e.g., trucks and buses) is not greater than 10 mph. The critical lengths of grade for these speed reductions are shown in Figure 3 – 5 Critical Length Versus Upgrade. Where reduction of grade is not practical, climbing lanes should be provided to meet these speed reduction limitations.

The criteria for a climbing lane and the adjacent shoulder are the same as for any travel lane except that the climbing lane should be clearly designated by the appropriate pavement markings. Entrance to and exit from the climbing lane shall follow the same criteria as other merging traffic lanes; however, the climbing lane should not be terminated until well beyond the crest of the vertical curve. Differences in superelevation should not be sufficient to produce a change in pavement cross slope between the climbing lane and through lane in excess of 0.04 feet per foot.

Recommended minimum gutter grades:

Rolling terrain - 0.5% Flat terrain - 0.3%

**Table 3 – 7**
**Recommended Maximum Grades in Percent**

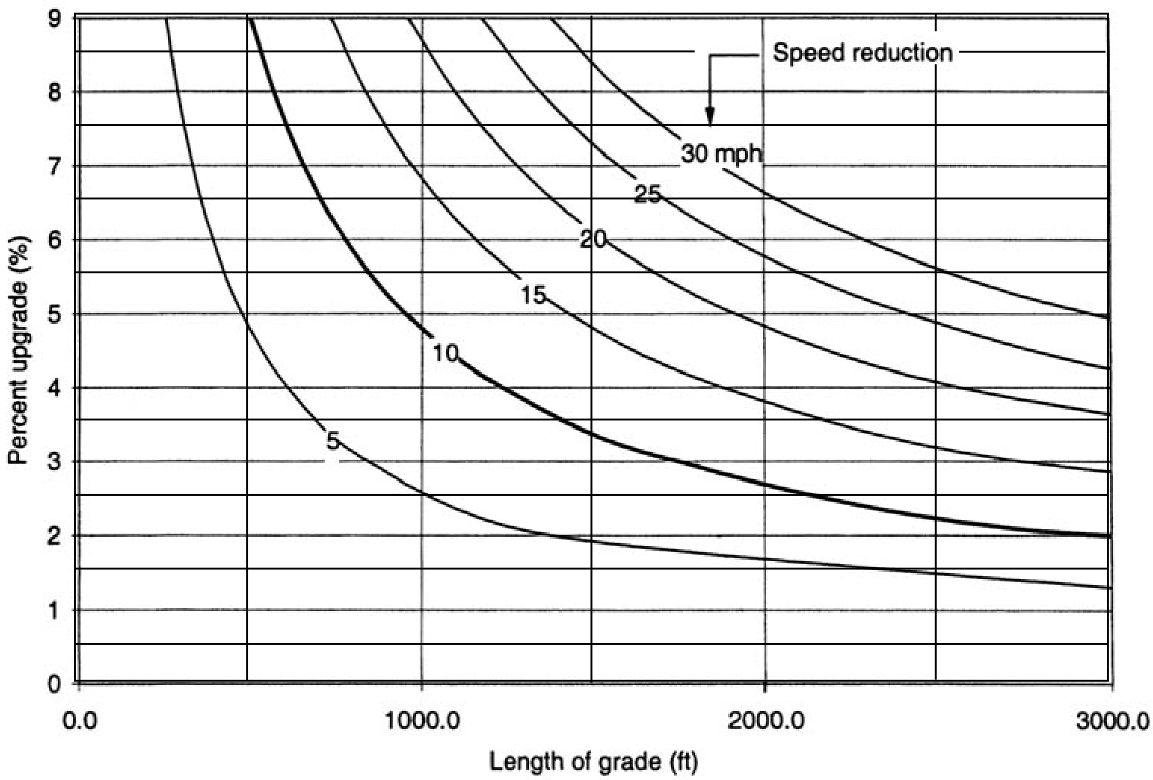
| TYPE OF ROADWAY | | FLAT TERRAIN | | | | | | | | | | | ROLLING TERRAIN | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DESIGN SPEED (mph) | | | | | | | | | | | DESIGN SPEED (mph) | | | | | | | | | | |
| | | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| Freeway | | --- | --- | --- | --- | --- | --- | 4 | 4 | 3 | 3 | 3 | --- | --- | --- | --- | --- | --- | 5 | 5 | 4 | 4 | 4 |
| Arterial* | Rural | --- | --- | --- | --- | 5 | 5 | 4 | 4 | 3 | 3 | 3 | -- | --- | --- | --- | 6 | 6 | 5 | 5 | 4 | 4 | 4 |
| | Urban | --- | --- | 8 | 7 | 7 | 6 | 6 | 5 | 5 | --- | --- | -- | --- | 9 | 8 | 8 | 7 | 7 | 6 | 6 | --- | --- |
| Collector* | Rural | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 5 | --- | --- | -10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 6 | --- | --- |
| | Urban | 9 | 9 | 9 | 9 | 9 | 8 | 7 | 7 | 6 | --- | --- | -12 | 12 | 11 | 10 | 10 | 9 | 8 | 8 | 7 | --- | --- |
| Local* | | 8 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 5 | --- | --- | 11 | 11 | 10 | 10 | 10 | 9 | 8 | 7 | 6 | --- | --- |
| Industrial** | | --- | --- | 4 | 4 | 4 | 4 | 3 | 3 | 3 | --- | --- | --- | --- | 5 | 5 | 5 | 5 | 4 | 4 | 4 | --- | --- |

* May be increased by 2 percent for urban streets under extreme conditions.

** Local and collector streets with significant (15% or more) truck traffic.

For short sections less than 500' and for one-way downgrades, the maximum gradient may be 1% steeper.

**Figure 3 – 5**
**Critical Length Versus Upgrade**




**Critical Lengths of Grade for Design, Assumed Typical Heavy Truck of 200 lb/hp, Entering Speed = 70 mph**

Source: 2011 AASHTO Greenbook, Figure 3 - 28,

### C.5.c Vertical Curves

Changes in grade should be connected by a parabolic curve (the vertical offset being proportional to the square of the horizontal distance). Vertical curves are required when the algebraic difference of intersecting grades exceeds the values given in Table 3 – 8 Maximum Change In Grade Without Using Vertical Curve. Table 3 – 9 Rounded K Values for Minimum Lengths Vertical Curves provides additional information. The length of vertical curve on a crest, as governed by stopping sight distance, is obtained from Figure 3 – 6 Length of Crest Vertical Curve (Stopping Sight Distance). The minimum length of a crest vertical curve to obtain minimum passing sight distance is given in Figure 3 – 7 Length of Crest Vertical Curve (Passing Sight Distance). The minimum length of a sag vertical curve, as governed by vehicle headlight capabilities, is obtained from Figure 3 – 8 Length of Sag Vertical Curve (Headlight Sight Distance).

Wherever feasible, curves longer than the minimum should be considered to improve both aesthetic and safety characteristics.

**Table 3 – 8**
**Maximum Change in Grade**
**Without Using Vertical Curve**

| Design Speed (mph) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Change in Grade in Percent | 1.20 | 1.10 | 1.00 | 0.90 | 0.80 | 0.70 | 0.60 | 0.50 | 0.40 | 0.30 | 0.20 |

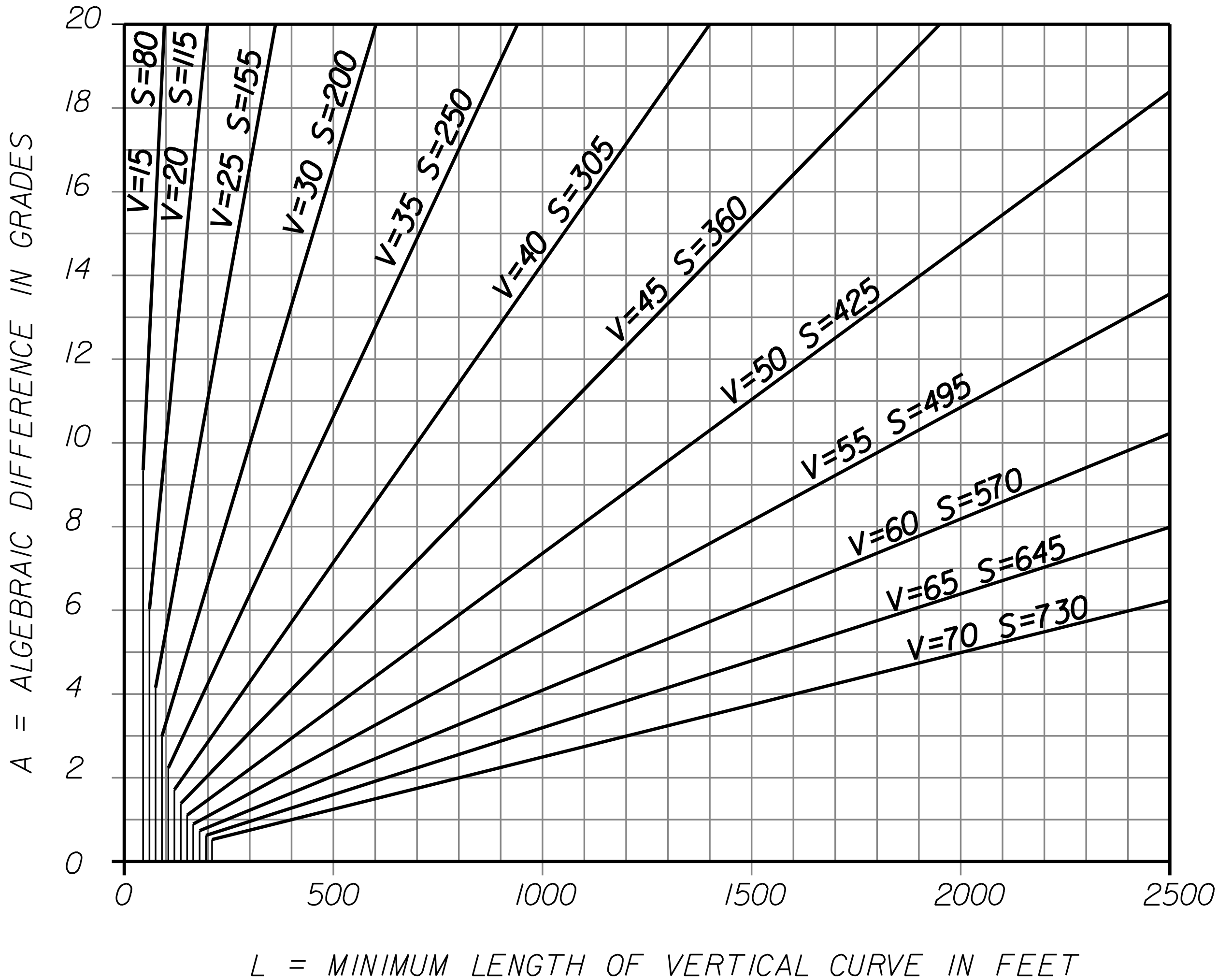
## Table 3 – 9 Rounded K Values for Minimum Lengths Vertical Curves

| Rounded K Values For Minimum Lengths Vertical Curves (Based upon an eye height of 3.50 feet and an object height of 2 feet above the road surface) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| L = KA<br>L = LENGTH OF VERTICAL CURVE, A = ALGEBRAIC DIFFERENCE OF GRADES IN PERCENT | | | | | | | | | | | |
| Design Speed (mph) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| K Values for Crest Vertical Curves | 7 | 12 | 19 | 29 | 44 | 61 | 84 | 114 | 151 | 193 | 247 |
| K Values for Sag Vertical Curves | 17 | 26 | 37 | 49 | 64 | 79 | 96 | 115 | 136 | 157 | 181 |

- The length of vertical curve must never be less than three times the design speed of the highway
- Curve lengths computed from the formula L = KA should be rounded upward when feasible
- The minimum lengths of vertical curves to be used on collectors, arterials and freeways are shown in the table below:

| Minimum Lengths for Vertical Curves on Collectors, Arterials, and Freeways (feet) | | | |
|---|---|---|---|
| Design Speed (mph) | 50 | 60 | 70 |
| Crest Vertical Curves (feet) | 300 | 400 | 500 |
| Sag Vertical Curves (feet) | 200 | 300 | 400 |

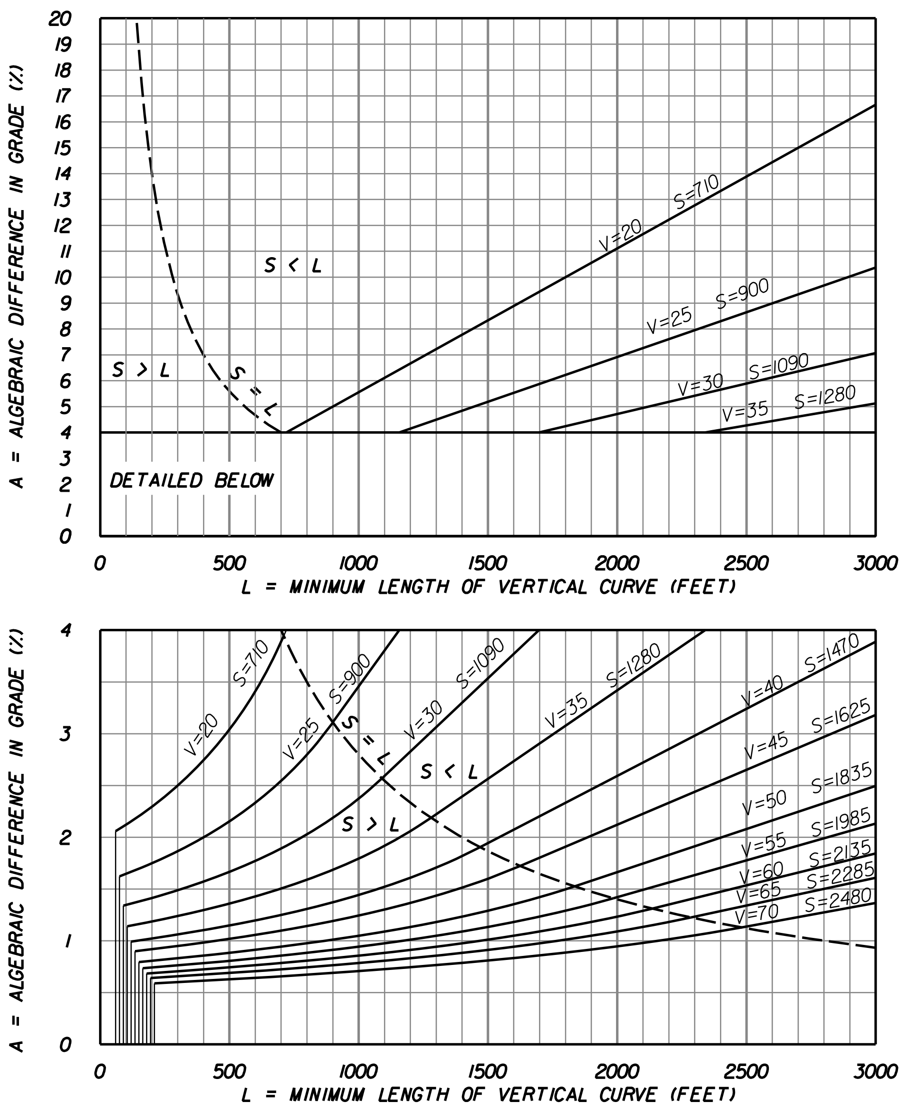
**Figure 3 – 6**
**Length of Crest Vertical Curve**
**(Stopping Sight Distance)**




Lengths of vertical curves are computed from the formula: $L = \frac{AS^2}{1329}$

A = Algebraic Difference In Grades In Percent
S = Sight Distance
L = Minimum Length of Vertical Curve In Feet

## Figure 3 – 7
## Length of Crest Vertical Curve
## (Passing Sight Distance)




The sight distance is computed from the following formulas:

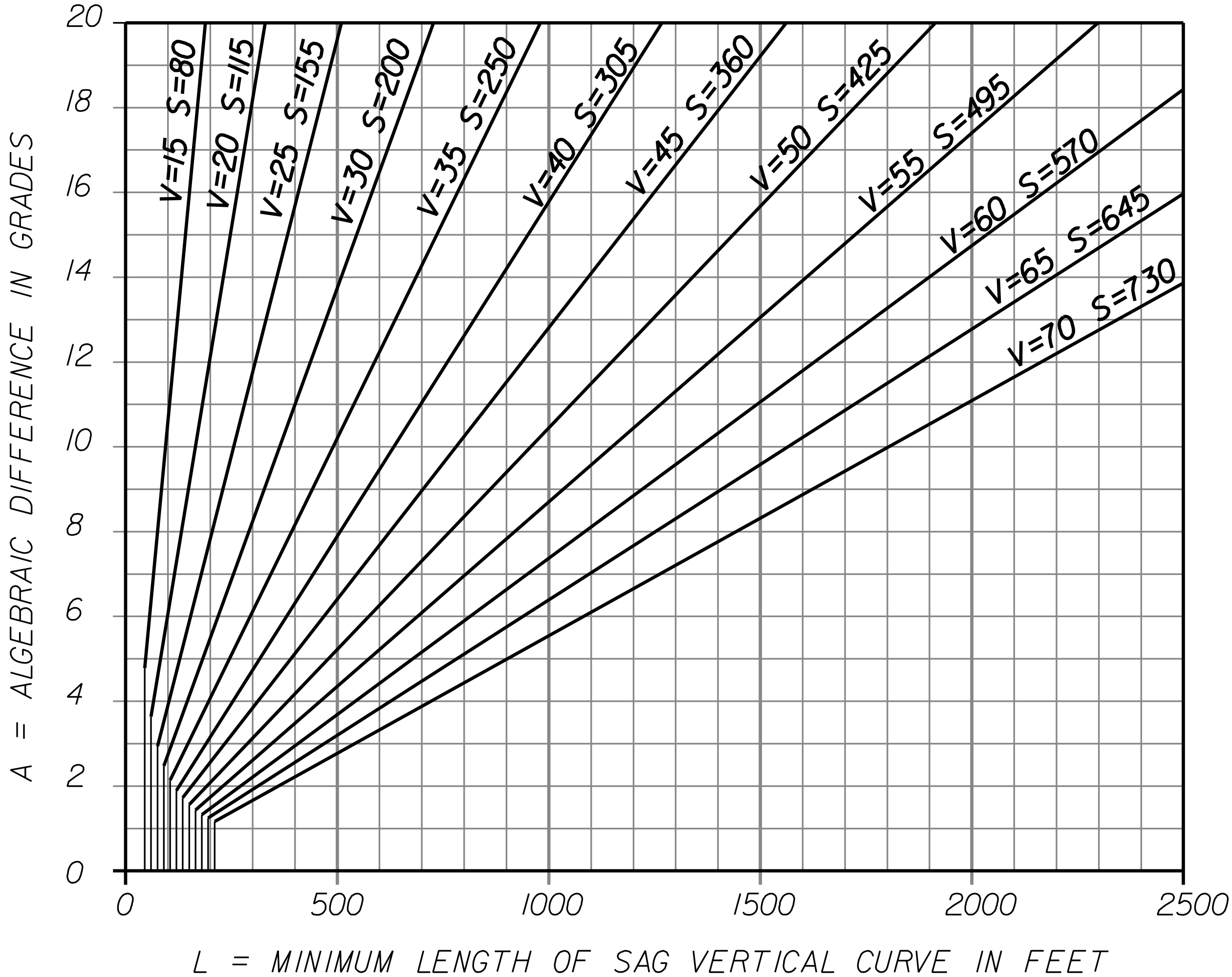
$S < L,\quad L = \frac{AS^2}{2800}$ $\qquad S > L,\quad L = 2S - \frac{2800}{A}$

A = Algebraic Difference in Grades, Percent
S = Sight Distance
L = Length of Vertical Curve

**Figure 3 – 8**
**Length of Sag Vertical Curve**
**(Headlight Sight Distance)**

***Lengths of vertical curves are computed from the formula:***

$$L = \frac{AS^2}{400 + 3.5(S)}$$



## C.6 Alignment Coordination

Horizontal and vertical alignment should not be designed independently. Poor combinations can spoil the good points of a design. Properly coordinated horizontal and vertical alignment can improve appearance, enhance community values, increase safety, and encourage uniform speed. Coordination of horizontal and vertical alignment should begin with preliminary design, during which stage adjustments can be readily made.

Proper combinations of horizontal alignment and profile can be obtained by engineering study and consideration of the following general controls:

- Curvature and grades should be in proper balance. Tangent alignment or flat curvature with steep grades and excessive curvature with flat grades are both poor design. A logical design is a compromise between the two conditions. Wherever feasible the roadway should "roll with" rather than "buck" the terrain.
- Vertical curvature superimposed on horizontal curvature, or vice versa, generally results in a more pleasing facility, but it should be analyzed for effect on driver's view and operation. Changes in profile not in combination with horizontal alignment may result in a series of disconnected humps to the driver for some distance.
- Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve. Drivers cannot perceive the horizontal change in alignment, especially at night. This condition can be avoided by setting the horizontal curve so it leads the vertical curve or by making the horizontal curve longer. Suitable design can be made by using design values well above the minimums.
- Sharp horizontal curvature should not be introduced at or near the low point of a pronounced sag vertical curve to prevent an undesirable distorted appearance. Vehicle speeds are often high at the bottom of grades and erratic operation may result, especially at night.
- On divided highways, variation of the median width and the use of independent vertical and horizontal alignment should be considered. Where right of way is available, a superior design without significant additional costs can result from the use of independent alignment.
- Horizontal alignment and profile should be made as flat as possible at interchanges and intersections where sight distance along both highways is

important. Sight distances above the minimum are desirable at these locations.

- Alignment should be designed to enhance scenic views for the motorists.
- In residential areas, the alignment should be designed to minimize nuisance to the neighborhood.

## C.7 Cross Section Elements

The design of the street or highway cross section should be predicated upon the design speed, terrain, adjacent land use, classification, and the type and volume of traffic expected. The cross section selected should be uniform throughout a given length of street or highway without frequent or abrupt changes.

### C.7.a Number of Lanes

The number of travel lanes is determined by several interrelated factors such as capacity, level of service, and service volume. (***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011***), and the current ***Highway Capacity Manual***)

### C.7.b Pavement

The paved surface of roadways shall be designed and constructed in accordance with the requirements set forth in ***Chapter 5 – Pavement Design and Construction***.

#### C.7.b.1 Pavement Width

Minimum lane widths for travel lanes, speed change lanes, turn lanes and passing lanes are provided in Table 3 - 10 Minimum Lane Widths. On multilane urban curb and gutter streets where there is insufficient space for a separate bicycle lane, consideration should be given to using unequal-width lanes. In such cases, the wider lane is located on the outside (right). This provides more space for large vehicles that usually occupy that lane, provides more space for bicycles, and allows drivers to keep their vehicles at a greater distance from the right edge. See ***Chapter 9 – Bicycle Facilities.***

## Table 3 – 10 Minimum Lane Widths

| Facility | | ADT (vpd) | Design Speed (mph) | Divided/ Undivided | Lane Width - FT | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Travel Lanes[1] | Speed Change Lanes | Turn Lanes[5] (LT/RT/MD) | Passing Lanes |
| Freeway | Rural | All | All | All | 12 | 12 | -- | -- |
| | Urban | All | All | All | 12 | 12 | -- | -- |
| Arterial | Rural | All | All | All | 12[8] | 12[8] | 12[8] | 12[8] |
| | Urban | All | > 45 | All | 12 | 12 | 12 | 12 |
| | | All | ≤ 45 | Undivided | 11[3] | 11[3] | 11[3, 6] | 11[3] |
| | | | | Divided | 11[3] | 11[3] | 11[3, 6] | 11[3] |
| Collector | Rural | > 1500 | All | All | 12[8] | 12[8] | 12[8] | 12[8] |
| | | 400 to 1500 | All | All | 11[3] | 11[3] | 11[3] | -- |
| | | < 400 | > 45 | All | 11 | 11 | 11[6] | -- |
| | | | ≤ 45 | All | 10 | 10 | 10 | -- |
| | Urban | All | All | All | 11[2, 3] | 11[2, 3] | 11[2, 6] | -- |
| Local | Rural | > 1500 | All | All | 12[8] | 12[8] | 12[8] | 12[8] |
| | | 400 to 1500 | All | All | 11[3] | -- | 11[3] | -- |
| | | < 400 | > 50 | All | 11[3] | -- | 11[3] | -- |
| | | | 45 to 50 | All | 10 | -- | 10 | -- |
| | | | < 45 | All | 9 | -- | 9 | -- |
| | Urban | All | All | All | 10[2,4] | -- | 10[7] | -- |

Footnotes

1. A minimum traveled way width equal to the width of two adjacent travel lanes (one way or two way) shall be provided on all rural facilities.
2. In industrial areas and where truck volumes are significant, 12’ lanes should be provided, but may be reduced to 11’ where right of way severely limited.
3. In constrained areas where truck and bus volumes are low and speeds are less than 35 mph, 10; lanes may be used.
4. In residential areas where right of way is severely limited, 9’ may be used.
5. Median turn lane widths shall not exceed 15’.
6. Turn Lane width should be same as Travel Lane width. May be reduced to 10’ where right of way is constrained.
7. Turn Lane width should be same as Travel Lane width. May be reduced to 9’ where truck volumes are low.
8. For design speeds below 50 mph, lane widths of 11 feet are acceptable.

#### C.7.b.2 Traveled Way Cross Slope (not in superelevation)

The selection of traveled way cross slope should be a compromise between meeting the drainage requirements and providing for smooth vehicle operation. The recommended traveled way cross slope is 0.02 feet per foot. When three lanes in each direction are necessary, the outside lane should have a cross slope of 0.03 feet per foot. The cross slope shall not be less than 0.015 feet per foot or greater than 0.04 feet per foot. The change in cross slope between adjacent through travel lanes should not exceed 0.04 feet per foot.

### C.7.c Shoulders

The primary functions of a shoulder are to provide emergency parking for disabled vehicles and an alternate path for vehicles during avoidance or other emergency maneuvers. In order to fulfill these functions satisfactorily, the shoulder should have adequate stability and surface characteristics. The design and construction of shoulders shall be in accordance with the requirements given in ***Chapter 5 – Pavement Design and Construction.***

Shoulders should be provided on all streets and highways incorporating open drainage. The absence of a contiguous emergency travel or storage lane is not only undesirable from a safety standpoint, but also is disadvantageous from an operations viewpoint. Disabled vehicles that must stop in a through lane impose a severe safety hazard and produce a dramatic reduction in traffic flow. Shoulders should be free of abrupt changes in slope, discontinuities, soft ground, or other hazards that would prevent the driver from retaining or regaining vehicle control.

Paved outside shoulders are required for rural high speed multilane highways and freeways. They provide added safety to the motorist, public transit and pedestrians, for accommodation of bicyclists, reduced shoulder maintenance costs, and improved drainage

#### C.7.c.1 Shoulder Width

Since the function of the shoulders is to provide an emergency storage or travel path, the desirable width of all shoulders should be at least 10 feet. Where economic or practical constraints are severe, it is permissible, but not desirable, to reduce the shoulder width. Outside shoulders shall be provided on all streets and highways with open drainage and should be at least 6 feet wide. Facilities with a heavy traffic volume or a significant volume of truck traffic SHOULD have outside shoulders at least 8 feet wide. The width of outside shoulders for two-lane, two-way shoulders shall not be less than the values given in Table 3 – 11 Shoulder Widths for Rural Highways.

Median shoulders are desirable on all multi-lane, non-curb and gutter divided streets and highways. For shoulder widths on multi-lane divided highways see Table 3 – 11.

**Table 3 – 11**
**Shoulder Widths for Rural Highways**

**Two Lane**

| Design Speed (mph) | Average Daily Traffic (2 – Way) | | |
|---|---|---|---|
| | 0 - 400 | 400 - 750 | 750 - 1600 |
| All | 2 feet | 6 feet | 8 feet |

**Multilane Divided**

| Number of Lanes Each Direction | Shoulder Width (feet) | | | |
|---|---|---|---|---|
| | Outside | | Median | |
| | Roadway | Bridge | Roadway | Bridge |
| 2 | 10 (min.) | 10 | 6 (min.) | 6 |
| 3 or more | 10 (min.) | 10 | 10 (min.) | 10 |

#### C.7.c.2 Shoulder Cross Slope

The shoulder serves as a continuation of the drainage system, therefore, the shoulder cross slope should be somewhat greater than the adjacent traffic lane. The cross slope of shoulders should be within the range given in Table 3 – 12 Shoulder Cross Slope.

**Table 3 – 12**
**Shoulder Cross Slope**

| | Shoulder Type | | |
|---|---|---|---|
| | Paved | Gravel or Crushed Rock | Turf |
| Shoulder Cross Slope (Percent) | 2 to 6% | 4 to 6% | 6 to 8% |

Notes: 1. Existing shoulder cross-slope (paved and unpaved) ≤ 12% may remain.

Source – 2011 AASHTO Greenbook, Section 4.4.3 Shoulder Cross Sections.

Whenever possible, shoulders should be sloped away from the traveled way to aid in their drainage. The combination of shoulder cross slope and texture should be sufficient to promote rapid drainage and to avoid retention of surface water. The maximum algebraic difference between the traveled way and adjacent shoulder should not be greater than 0.07 feet per foot. Shoulders on the outside of superelevated curves should be rounded (vertical curve) to avoid an excessive break in cross slope and to divert a portion of the drainage away from the adjacent traveled way.

### C.7.d Sidewalks

The design of sidewalks is affected by many factors, including, but not limited to, pedestrian volume, roadway type, characteristics of vehicular traffic, and other design elements. ***Chapter 8 – Pedestrian Facilities*** of this Manual and ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***, present the various factors that influence the design of sidewalks and other pedestrian facilities.

Sidewalks should be constructed in conjunction with new construction and major reconstruction in or within one mile of an urban area. As a general rule, sidewalks should be constructed on both sides of the roadway. Exceptions may be made where physical barriers (e.g., a canal paralleling one side of the roadway) would substantially reduce the expectation of pedestrian use of one side of the roadway. Also, if only one side is possible, sidewalks should be available on the same side of the road as transit stops or other pedestrian generators.

The decision to construct a sidewalk in a rural area should be based on engineering judgment, after observation of existing pedestrian traffic and expectation of additional demand, should a sidewalk be made available.

Sidewalks should be constructed as defined in this Manual - ***Chapter 8 – Pedestrian Facilities***. In areas of high use, refer to the ***Highway Capacity Manual, Volume 3, Chapter 23, Off-Street Pedestrian and Bicycle Facilities (2010)*** for calculation of desirable additional width.

Curb ramps shall be provided at all intersections with curb (***Section 336.045 (3), Florida Statutes)***. In addition to the design criteria provided in this chapter, the ***2006 Americans with Disabilities Act Standards for Transportation Facilities*** as required by 49 C.F.R 37.41 or 37.43 and the ***2012 Florida Accessibility Code for Building Construction*** as required by 61G20-4.002 impose additional requirements for the design and construction of pedestrian facilities.

### C.7.e Medians

Median separation of opposing traffic lanes provides a beneficial safety feature and should be used wherever feasible. Separation of the opposing traffic also reduces the problem of headlight glare, thus improving safety and comfort for night driving. When sufficient width of medians is available, some landscaping is also possible.

The use of medians often aids in the provision of drainage for the roadway surface, particularly for highways with six or more traffic lanes. The median also provides a vehicle refuge area, improves the safety of pedestrian crossings, provides a logical location for left turn auxiliary lanes, and provides the means for future addition of traffic lanes and mass transit. In many situations, the median strip aids in roadway delineation and the overall highway aesthetics.

Median separation is required on the following streets and highways:

- Freeways
- All streets and highways, rural and urban, with 4 or more travel lanes and with a design speed of 40 mph or greater

Median separation is desirable on all other multi-lane roadways to enhance pedestrian crossings.

The nature and degree of median separation required is dependent upon the design speed, traffic volume, adjacent land use, and the frequency of access. There are basically two approaches to median separation. The first is the use of horizontal separation of opposing lanes to reduce the probability of vehicles crossing the median into incoming traffic. The second method is to attempt to limit crossovers by introducing a positive median barrier structure.

In rural areas, the use of wide medians is not only aesthetically pleasing, but is often more economical than barriers. In urban areas where space and/or economic constraints are severe, the use of barriers is permitted to fulfill the requirements for median separation.

Uncurbed medians should be free of abrupt changes in slope, discontinuities, soft ground, or other hazards that would prevent the driver from retaining or regaining control of the vehicle. Consideration should be given to increasing the width and decreasing the slope of medians on horizontal curves. The requirements for a hazard free median environment are given in ***Chapter 4 – Roadside Design***, and shall be followed in the design and construction of medians.

#### C.7.e.1 Type of Median

A wide, gently depressed median is the preferred design. This type allows a reasonable vehicle recovery area and aids in the drainage of the adjacent shoulders and travel lanes. Where space and drainage limitations are severe, narrower medians, flush with the roadway, or raised medians, are permitted. Raised medians should be used to support pedestrian crossings of multi-laned streets and highways.

### C.7.e.2 Median Width

The median width is defined as the horizontal distance between the inside (median) edge of travel lanes of the opposing roadways. The selection of the median width for a given type of street or highway is primarily dependent on design speed and traffic volume. Since the probability of crossover crashes is decreased by increasing the separation, medians should be as wide as practicable. Median widths in excess of 30 feet to 35 feet reduce the problem of disabling headlight glare from opposing traffic.

The minimum permitted widths of freeway medians are given in Table 3 – 13 Median Width for Freeways (Urban and Rural). Where the expected traffic volume is heavy, the widths should be increased over these minimum values. Median barriers shall be used on freeways when these minimum values are not attainable.

The minimum permitted median widths for multi-lane rural highways are given in Table 3 – 14 Median Width for Rural Highways (Multilane Facilities). On urban streets, the median widths shall not be less than the values given in Table 3 – 14. Where median openings or access points are frequent, the median width should be increased.

The minimum median widths given in these tables may have to be increased to meet the requirements for cross slopes, drainage, and turning movements (C.9 Intersection Design, this chapter). The median area should also include adequate additional width to allow for expected additions of through lanes and left turn auxiliary lanes. Where the median width is sufficient to produce essentially two separate, independent roadways, the left side of each roadway shall meet the requirements for roadside clear zone. Changes in the median width should be accomplished by gently flowing horizontal alignment of one or both of the separate roadways.

**Table 3 – 13**
**Median Width for Freeways**
**(Urban and Rural)**

| Design Speed (mph) | Minimum Permitted Median Width (feet) |
|---|---|
| 60 and Over | 60 ** |
| Under 60 | 40 * |

* Applicable for urban areas ONLY.

** Applicable for new construction ONLY.
(40 feet minimum allowed when lanes added to median)

**Table 3 – 14**
**Median Width for Rural Highways**
**(Multilane Facilities)**

| Design Speed (mph) | Minimum Width (feet) |
|---|---|
| 55 and Over | 40 |
| Under 55 | 22 |

**Median Width for Urban Streets**

| Design Speed (mph) | Minimum Width (feet) |
|---|---|
| 50 | 19.5 |
| 45 and Less | 15.5 |

Paved medians with a minimum width of 10 feet may be used for two-way turn lanes and painted or raised medians when design speeds are 40 mph or less.

### C.7.e.3 Median Slopes

A vehicle should be able to transverse a median without turning over and with sufficient smoothness to allow the driver a reasonable chance to control the vehicle. The transition between the median slope and the shoulder (or pavement) slope should be smooth, gently rounded, and free from discontinuities.

The median cross slope should not be steeper than1:6 (preferably not steeper than 1:10). The depth of depressed medians may be controlled by drainage requirements. Increasing the width of the median, rather than increasing the cross slope, is the proper method for developing the required median depth.

Longitudinal slopes (median profile parallel to the roadway) should be shallow and gently rounded at intersections of grade. The longitudinal slope, relative to the roadway slope, shall not exceed a ratio of 1:10 and preferably 1:20. The change in longitudinal slope shall not exceed 1:8 (change in grade of 12.5 %).

### C.7.e.4 Median Barriers

The primary objective for placing a barrier structure in the median is to prevent vehicles from entering the opposing traffic stream, either accidentally or intentionally. Median barriers may also be used to reduce the glare produced by oncoming vehicle headlights. When selecting the type of barrier, care should be exercised to avoid headlight flicker through barriers.

The use of median barriers to reduce horizontal separation is permitted on facilities with substantially full control of access. Frequent openings in the barrier for intersections or crossovers expose the barrier end, which constitute severe hazard at locations with an inherently high crash potential and should be shielded. Median barriers may be considered for urban freeways and high speed arterials with controlled access.

Median barriers shall be used on controlled access facilities if the median width is less than the minimum permitted values given in Table 3 – 13. The median barrier should not be placed closer than 10 feet from the inside edge of traveled way. Further requirements for median barriers are given in ***Chapter 4 – Roadside Design***.

### C.7.f Roadside Clear Zone

The roadside clear zone is that area outside the traveled way available for use by errant vehicles. Vehicles frequently leave the traveled way during avoidance maneuvers, due to loss of control by the driver (e.g., falling asleep) or due to collisions with other vehicles. The primary function of the clear zone is to allow space and time for the driver to retain control of his vehicle and avoid or reduce the consequences of collision with roadside objects. This area also serves as an emergency refuge location for disabled vehicles.

The design of the roadway must also provide for adequate drainage of the roadway. Drainage swales within the clear zone should be gently rounded and free of discontinuities. Where large volumes of water must be carried, the approach should be to provide wide, rather than deep drainage channels. Side slopes and drainage swales that lie within the clear zone should be free of protruding drainage structures (***Chapter 4 – Roadside Design, Section D.6.c. Culverts***).

In the design of the roadside, the designer should consider the consequences of a vehicle leaving the traveled way at any location. It should always be the policy that protection of vehicles and occupants shall take priority over the protection of roadside objects. Further criteria and requirements for safe roadside design are given in ***Chapter 4 – Roadside Design***.

### C.7.f.1 Roadside Clear Zone Width

The clear zone width is defined as follows:

- Flush Shoulder Sections - measured from the edge of the outside motor vehicular traveled way
- Urban Curbed Sections ≤ 45 mph - measured from the face of the curb

The minimum permitted widths are provided in Table 3 – 15 Minimum Width of Clear Zon***e.*** These are minimum values only and should be increased wherever practical.

In rural areas, it is desirable, and frequently economically feasible, to increase the width of the clear zone. Where traffic volumes and speeds are high, the width should be increased. The clear zone on the outside of horizontal curves should be increased due to the possibility of vehicles leaving the roadway at a steeper angle.

**Table 3 – 15 Minimum Width of Clear Zone**

| Type of Facility | DESIGN SPEED (mph) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 25 and Below | 30 | 35 | 40 | 45 | 50 | 55 | 60 and Above |
| | MINIMUM CLEAR ZONE (feet) | | | | | | | |
| Flush Shoulder • | 6 | 6 Local<br>10 Collectors<br>14 Arterials | 6 Local<br>10 Collectors<br>14 Arterials | 10 Collectors<br>14 Arterials | 14 Arterials and Collectors ADT < 1500<br>18 Arterials and Collectors ADT ≥ 1500 | 14 Arterials and Collectors ADT < 1500<br>18 Arterials and Collectors ADT ≥ 1500 | 18 Arterials and Collectors ADT < 1500<br>24 Arterials and Collectors ADT ≥ 1500 | 18 Arterials and Collectors ADT < 1500<br>30 Arterials and Collectors ADT ≥ 1500 |
| Curbed* | 1 ½ | 4 ** | 4 ** | 4 ** | 4 ** | N/A •• | N/A •• | N/A •• |

* From face of curb.

** On projects where the 4 foot minimum offset cannot be reasonably obtained and other alternatives are deemed impractical, the minimum may be reduced to 1 ½'.

• Use rural for urban facilities when no curb and gutter is present. Measured from the edge of through travel lane on rural section.

•• Curb and gutter not to be used on facilities with design speed > 45 mph.

NOTE: ADT in Table 3 – 15 refers to Design Year ADT.

#### C.7.f.2 Roadside Slopes

The slopes of all roadsides should be as flat as possible to allow for safe traversal by out of control vehicles. A slope of 1:4 or flatter should be used. The transition between the shoulder and adjacent side slope should be rounded and free from discontinuities. The adjacent side slope, within the clear zone, shall not be steeper than 1:3. The side slopes should be reduced flatter on the outside of horizontal curves.

Where roadside ditches or cuts require backslope, these slopes should not exceed 1:3 in steepness within the clear zone. The desirable backslope is 1:4. Ditch bottoms should be at least 4 feet wide and can be flat or gently rounded.

#### C.7.f.3 Criteria for Guardrail

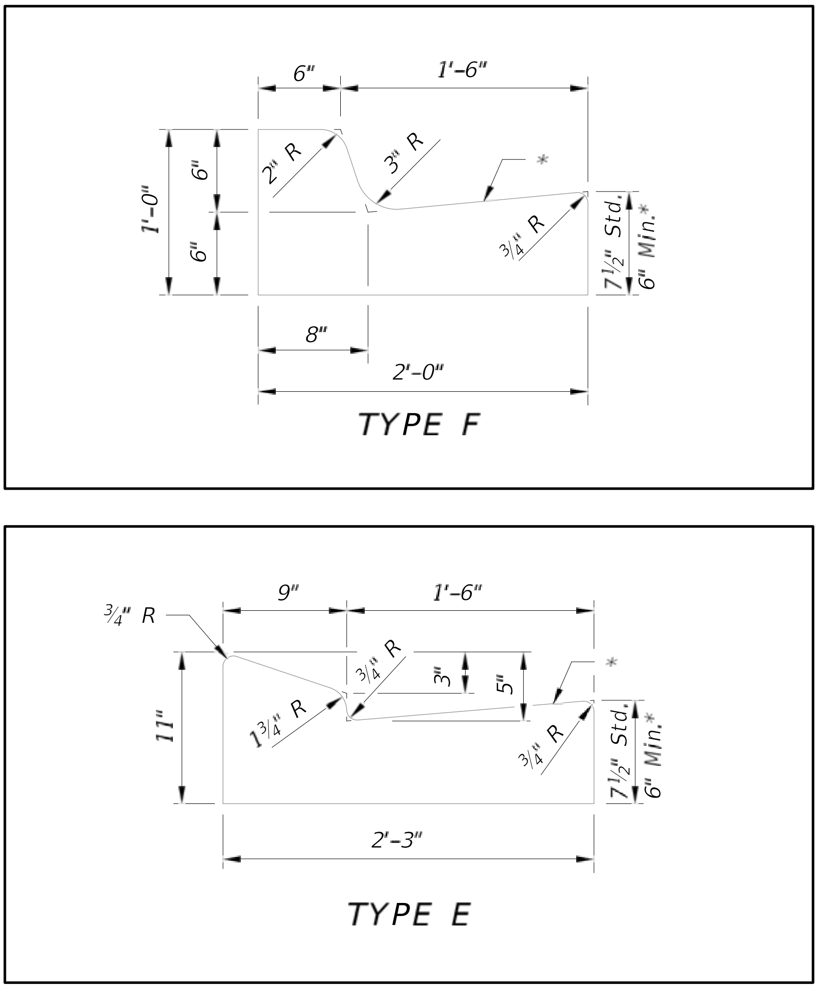
If space and economic constraints are severe, it is permissible, but not desirable, to use guardrails in lieu of the requirements for width and slope of clear zone. Where the previously described requirements for clear zone are not met, guardrails (or other longitudinal barriers) should be considered. Guardrails should also be considered for protection of pedestrian pathways or protection from immovable roadside hazards.

The general policy to be followed is that guardrails should be used if impact with the guardrail is less likely or considered less severe than impact with roadside objects. Further requirements and design criteria for guardrails are given in ***Chapter 4 – Roadside Design***.

### C.7.g Curbs

Curbs may be used to provide drainage control and to improve delineation of the roadway. Curbs are generally designed with a gutter to form a combination curb and gutter section. Sloping curbs are used along the outside edge of the roadway to discourage vehicles from leaving the roadway. In Florida, the standard curb of this type is 6 inches in height. See Figure 3 – 9 Standard Detail for FDOT Type F and E Curbs for examples of sloping curbs. These curbs are not to be used on facilities with design speeds greater than 45 mph.

**Figure 3 – 9 Standard Detail for FDOT Type F and E Curbs**



### C.7.h Parking

When on-street parking is to be an element of design, parallel parking should be considered. Under certain circumstances, angle parking is an allowable form of street parking. The type of on-street parking selected should depend on the specific function and width of the street, the adjacent land use, traffic volume, as well as existing and anticipated traffic operations.

It can generally be stated that on-street parking decreases through capacity, impedes traffic flow, and increases crash potential. However, where parking is needed, and adequate off-street parking facilities are not available or feasible, on-street parking may be necessary.

### C.7.i Right of Way

The acquisition of sufficient right of way is necessary in order to provide space for a safe street or highway. The width of the right of way required depends on the design of the roadway, the arrangement of bridges, underpasses and other structures, and the need for cuts or fills. The right of way acquired should be sufficient to:

- Allow development of the full cross section, including adequate medians and roadside clear zones. Determination of the necessary width requires that adequate consideration also be given to the accommodation of utility poles beyond the clear zone.
- Allow the layout of safe intersections, interchanges, and other access points.
- Allow adequate sight distance at all points, particularly on horizontal curves, at an intersection, and other access points.
- Allow, where appropriate, additional buffer zones to improve roadside safety, noise attenuation, and the overall aesthetics of the street or highway.
- Allow adequate space for placement of pedestrian and bicycle facilities, including curb ramps, bus bays, and transit shelters, where applicable.

- Allow for future lane additions, increases in cross section, or other improvement. Frontage roads should also be considered in the ultimate development of many high volume facilities.
- Allow treatment of stormwater runoff.
- Allow construction of future grade separations or other intersection improvements at selected crossroads.
- Allow corner cuts for upstream corner crossing drainage systems and placement of poles, boxes, and other visual screens out of the critical sight triangle.
- Allow landscaping and irrigation as required for the project.

The acquisition of wide rights of way is costly, but it may be necessary to allow the construction and future improvement of safe streets and highways. The minimum right of way should be at least 50 feet for all two-lane roads. For pre-existing conditions, when the existing right of way is less than 50 feet, efforts should be made to acquire the necessary right of way.

Local cul-de-sac and dead end streets having an ADT of less than or equal to 400 and a length of 600 feet or less, may utilize a right of way of less than 50 feet, if all elements of the typical section meet the standards included in this Manual.

The right of way for frontage roads may be reduced depending on the typical section requirements and the ability to share right of way with the adjacent street or highway facility.

### C.7.j Changes in Typical Section

#### C.7.j.1 General Criteria

Changes in cross section should be avoided. When changes in widths, slopes, or other elements are necessary, they should be affected in a smooth, gradual fashion.

#### C.7.j.2 Lane Deletions and Additions

The addition or deletion of traffic or bicycle lanes should be undertaken on tangent sections of roadways. The approach to lane deletions and additions should have ample advance warning and sight distance.

The termination of lanes (including auxiliary lanes) shall meet the general requirements for merging lanes. See ***Section C.9.c.1*** for additional information.

Where additional lanes are intermittently provided on two-lane, two-way highways, median separation should be considered.

#### C.7.j.3 Preferential Lanes

To increase the efficiency and separation of different vehicle movements, preferential use lanes, such as bike lanes and bus lanes, should be considered. These lanes are often an enhancement to corridor safety and increase the horizontal clearance to roadside aboveground fixed objects. The ***MUTCD, Chapter 3D*** provides further information on preferential lane markings. See ***Chapter 9 – Bicycle Facilities*** for information on marking bicycle lanes.

#### C.7.j.4 Structures

The pavement, median, and shoulder width, and sidewalks should be carried across structures such as bridges and box culverts. Shoulder widths for multi-lane rural divided highway bridges may be reduced as shown in Table 3 – 11. The designer should evaluate the economic practicality of utilizing dual versus single bridges for roadway sections incorporating wide medians.

The minimum roadway width for bridges on urban streets with curb and gutter shall be the same as the curb-to-curb width of the approach roadway. Sidewalks on the approaches should be carried across all structures. Curbed sidewalks should not be used adjacent to traffic lanes when design speeds exceed 45 mph. When the bridge rail (barrier wall) is placed between the traffic and sidewalk, it should be offset a minimum distance of 2½ feet from the edge of the travel lane, wide curb lane or bicycle lane. For long (500 feet or greater), and/or high level bridges, it is desirable to provide an offset distance that will accommodate a disabled vehicle. The transition from the bridge to the adjacent roadway section may be made by dropping the curb at the first intersection or well in advance of the traffic barrier, or reducing the curb in front of the barrier to a low sloping curb with a gently sloped traffic face. See ***Chapter 17 – Bridges and Other Structures*** for additional requirements.

**C.7.j.4.(a) Horizontal Clearance**

Supports for bridges, barriers, or other structures should be placed at or beyond the required shoulder. Where possible, these structures should be located outside of the required clear zone.

**C.7.j.4.(b) Vertical Clearance**

Vertical clearance should be adequate for the type of expected traffic. Freeways and arterials shall have a vertical clearance of at least 16 feet-6 inches (includes 6 inch allowance for future resurfacing). Other streets and highways should have a clearance of 16 feet unless the provision of a reduced clearance is fully justified by a specific analysis of the situation (14 feet minimum). The minimum vertical clearance for a pedestrian or shared use bridge over a roadway is 17 feet. The minimum vertical clearance for a bridge over a railroad is 23 feet; however additional clearance may be required by the rail owner.

**C.7.j.4.(c) End Treatment**

The termini of guardrails, bridge railings, abutments, and other structures should be constructed to protect vehicles and their occupants from serious impact. Requirements for end treatment of structures are given in ***Chapter 4 – Roadside Design***.

## C.8 Access Control

All new facilities (and existing when possible) should have some degree of access control, since each point of access produces a traffic conflict. The control of access is one of the most effective, efficient, and economical methods for improving the capacity and safety characteristics of streets and highways. The reduction of the frequency of access points and the restriction of turning and crossing maneuvers, which should be primary objectives, is accomplished more effectively by the design of the roadway geometry than by the use of traffic control devices. Design criteria for access points are presented under the general requirements for intersection design.

### C.8.a Justification

The justification for control of access should be based on several factors, including safety, capacity, economics, and aesthetics.

### C.8.b General Criteria

#### C.8.b.1 Location of Access Points

All access locations should have adequate sight distance available for the safe execution of entrance, exit, and crossing maneuvers.

Locations of access points near structures, decision points, or the termination of street or highway lighting should be avoided.

Driveways should not be placed near intersections or other points that would tend to produce traffic conflict.

#### C.8.b.2 Spacing of Access Points

The spacing of access points should be adequate to prevent conflict or mutual interference of traffic flow.

Separation of entrance and exit ramps should be sufficient to provide adequate distance for required weaving maneuvers.

Adequate spacing between access and decision points is necessary to avoid burdening the driver with the need for rapid decisions or maneuvers.

Frequent median openings should be avoided.

The use of a frontage road or other auxiliary roadways is recommended on arterials and higher classifications where the need for direct driveway or minor road access is frequent.

#### C.8.b.3 Restrictions of Maneuvers

Where feasible, the number and type of permitted maneuvers (crossing, turning slowing, etc.) should be restricted.

The restriction of crossing maneuvers may be accomplished by the use of grade separations and continuous raised medians.

The restriction of left turns is achieved most effectively by continuous medians.

Channelization should be considered for the purposes of guiding traffic flow and reducing vehicle conflicts.

#### C.8.b.4 Auxiliary Lanes

Deceleration lanes for right turn exits (and left turns, where permitted) should be provided on all high-speed facilities. These turn lanes should not be excessive or continuous, since they complicate pedestrian crossings and bicycle/motor vehicle movements.

Storage (or deceleration lanes) to protect turning vehicles should be provided, particularly where turning volumes are significant.

Special consideration should be given to the provisions for deceleration, acceleration, and storage lanes in commercial or industrial areas with significant truck/bus traffic.

### C.8.b.5 Grade Separation

Grade separation interchange design should be considered for junctions of high volume arterial streets and highways.

Grade separation (or an interchange) should be utilized when the expected traffic volume exceeds the intersection capacity.

Grade separation should be considered to eliminate conflict or long waiting periods at potentially hazardous intersections.

### C.8.b.6 Roundabouts

Roundabouts have proven safety and operational characteristics and should be evaluated as an alternative to conventional intersections whenever practical. Modern roundabouts, when correctly designed, are a proven safety countermeasure to conventional intersections, both stop controlled and signalized. In addition, when constructed in appropriate locations, drivers will experience less delay with modern roundabouts. ***NCHRP Report 672. Roundabouts: An Informational Guide***, is adopted by FHWA and establishes criteria and procedures for the justification, operational and safety analysis of modern roundabouts in the United States. The modern roundabout is characterized by the following:

- A central island of sufficient diameter to accommodate vehicle tracking and to provide sufficient deflection to promote lower speeds
- Entry is by gap acceptance through a yield condition at all legs
- Speeds through the intersection are 25 mph or less

Roundabouts should be considered under the following conditions:

1 New construction
2. Reconstruction
3. Traffic Operations improvements
4. Resurfacing (3R) with Right of Way acquisition
5. Need to reduce frequency and severity of crashes

### C.8.c Control for All Limited Access Highways

Entrances and exits on the right side only are highly desirable for all limited access highways. Acceleration and deceleration lanes are mandatory. Intersections shall be accomplished by grade separation (interchange) and should be restricted to connect with arterials or collector roads.

The control of access on freeways should conform to the requirements given in Table 3 – 16 Access Control for All Limited Access Highways. The spacing of exits and entrances should be increased wherever possible to reduce conflicts. Safety and capacity characteristics are improved by restricting the number and increasing the spacing of access points.

**Table 3 – 16**
**Access Control for All Limited Access Highways**

| | Urban | Rural |
|---|---|---|
| Minimum Spacing | | |
| Interchanges | 1 to 3 miles | 3 to 25 miles |
| Maneuver Restrictions | | |
| Crossing Maneuvers | Via Grade Separation Only | |
| Exit and Entrance | From Right Side Only | |
| Turn Lane Required | Acceleration Lane at all Entrances<br>Deceleration Lane at all Exits | |

### C.8.d Control of Urban and Rural Streets and Highways

The design and construction of urban, as well as rural, highways should be governed by the general criteria for access control previously outlined. In addition, the design of urban streets should be in accordance with the criteria listed below:

- The general layout of local and collector streets should follow a branching network, rather than a highly interconnected grid pattern.

- The street network should be designed to reduce, consistent with origin/destination requirements, the number of crossing and left turn maneuvers.
- The design of the street layout should be predicated upon reducing the need for traffic signals.
- The use of a public street or highway as an integral part of the internal circulation pattern for commercial property should be discouraged.
- The number of driveway access points should be restricted as much as possible through areas of strip development.
- Special consideration should be given to providing turn lanes (auxiliary lane for turning maneuvers) where the total volume or truck/bus volume is high.
- Major traffic generators may be exempt from the restrictions on driveway access if the access point is designed as a normal intersection adequate to handle the expected traffic volume.

These are minimum requirements only; it is generally desirable to use more stringent criteria for control of access.

The design of rural highways should be in accordance with the general criteria for access control for urban streets. The use of acceleration and deceleration lanes on all high-speed highways, particularly if truck and bus traffic is significant, is strongly recommended.

### C.8.e Land Development

It should be the policy of each agency with responsibility for street and highway design, construction, or maintenance to promote close liaison with utility, lawmaking, zoning, building, and planning agencies. Cooperation should be solicited in the formulation of laws, regulations, and master plans for land use, zoning, and road construction. Further requirements and criteria for access control and land use relationships are given in ***Chapter 2 – Land Development***.

## C.9 Intersection Design

Intersections increase traffic conflicts and the demands on the driver, and are inherently hazardous locations. The design of an intersection should be predicated on reducing motor vehicle, bicycle, and pedestrian conflicts, minimizing the confusion and demands on the driver for rapid and/or complex decisions, and providing for smooth traffic flow. The location and spacing of intersections should follow the requirements presented in C.8 Access Control, this chapter. Intersections should be designed to minimize time and distance of all who pass through or turn at an intersection.

The additional effort and expense required to provide a high quality intersection is justified by the corresponding safety benefits. The overall reduction in crash potential derived from a given expenditure for intersection improvements is generally much greater than the same expenditure for improvements along an open roadway. Properly designed intersections increase capacity, reduce delays, and improve safety.

One of the most common deficiencies that may be easy to correct is lack of adequate left turn storage.

The requirements and design criteria contained in this section are applicable to all driveways, intersections, and interchanges. All entrances to, exits from, or interconnections between streets and highways are subject to these design standards.

### C.9.a General Criteria

The layout of a given intersection may be influenced by constraints unique to a particular location or situation. The design shall conform to sound principles and criteria for safe intersections. The general criteria include the following:

- The layout of the intersection should be as simple as is practicable. Complex intersections, which tend to confuse and distract the driver, produce inefficient and hazardous operations.
- The intersection arrangement should not require the driver to make rapid or complex decisions.

- The layout of the intersection should be clear and understandable so a proliferation of signs, signals, or markings is not required to adequately inform and direct the driver.
- The design of intersections, particularly along a given street or highway, should be as consistent as possible.
- The approach roadways should be free from steep grades and sharp horizontal or vertical curves.
- Intersections with driveways or other roadways should be as close to right angle as possible.
- Adequate sight distance should be provided to present the driver a clear view of the intersection and to allow for safe execution of crossing and turning maneuvers.
- The design of all intersection elements should be consistent with the design speeds of the approach roadways.
- The intersection layout and channelization should encourage smooth flow and discourage wrong way movements.
- Special attention should be directed toward the provision of safe roadside clear zones.
- The provision of auxiliary lanes should be in conformance with the criteria set forth in C.8 Access Control, this chapter.
- The requirements for bicycle and pedestrian movements should receive special consideration.

### C.9.b Sight Distance

Inadequate sight distance is a contributing factor in the cause of a large percentage of intersection crashes. The provision of adequate sight distance at intersections is absolutely essential and should receive a high priority in the design process.

#### C.9.b.1 General Criteria

General criteria to be followed in the provision of sight distance include the following:

- Sight distance exceeding the minimum stopping sight distance should be provided on the approach to all intersections (entrances, exits, stop signs, traffic signals, and intersecting roadways). The use of proper approach geometry free from sharp horizontal and vertical curvature will normally allow for adequate sight distance.
- The approaches to exits or intersections (including turn, storage, and deceleration lanes) should have adequate sight distance for the design speed and also to accommodate any allowed lane change maneuvers.
- Adequate sight distance should be provided on the through roadway approach to entrances (from acceleration or merge lanes, stop or yield signs, driveways or traffic signals) to provide capabilities for defensive driving. This lateral sight distance should include as much length of the entering lane or intersecting roadway as is feasible. A clear view of entering vehicles is necessary to allow through traffic to aid merging maneuvers and to avoid vehicles that have "run" or appear to have the intention of running stop signs or traffic signals.
- Approaches to school or pedestrian crossings and crosswalks should have sight distances exceeding the minimum values. This should also include a clear view of the adjacent pedestrian pathways or shared use paths.
- Sight distance in both directions should be provided for all entering roadways (intersecting roadways and driveways) to allow entering vehicles to avoid through traffic. See ***Section C.9.B.4*** for further information.
- Safe stopping sight distances shall be provided throughout all intersections, including turn lanes, speed change lanes, and turning roadways.
- The use of lighting (***Chapter 6 – Lighting***) should be considered to improve intersection sight distance for night driving.

### C.9.b.2 Obstructions to Sight Distance

The provisions for sight distance are limited by the street or highway geometry and the nature and development of the area adjacent to the roadway. Where line of sight is limited by vertical curvature or obstructions, stopping sight distance shall be based on the eye height of 3.50 feet and an object height of 2.0 feet. At exits or other locations where the driver may be uncertain as to the roadway alignment, a clear view of the pavement surface should be provided. At locations requiring a clear view of other vehicles or pedestrians for the safe execution of crossing or entrance maneuvers, the sight distance should be based on a driver's eye height of 3.50 feet and an object height of 3.00 feet (preferably 1.50 feet). The height of eye for truck traffic may be increased for determination of line of sight obstructions for intersection maneuvers. Obstructions to sight distance at intersections include the following:

- Any property not under the highway agency's jurisdiction, through direct ownership or other regulations, should be considered as an area of potential sight distance obstruction. Based on the degree of obstruction, the property should be considered for acquisition by deed or easement.
- Areas which contain vegetation (trees, shrubbery, grass, etc.) that cannot easily be trimmed or removed by regular maintenance activity should be considered as sight obstructions.
- Parking lanes shall be considered as obstructions to line of sight. Parking shall be prohibited within clear areas required for sight distance at intersections.
- Large (or numerous) poles or support structures for lighting, signs, signals, or other purposes that significantly reduce the field of vision within the limits of clear sight shown in Figure 3 – 11 Departure Sight Triangle in ***Section C.9.b.4***. may constitute sight obstructions. Potential sight obstructions created by poles, supports, and signs near intersections should be carefully investigated.

In order to ensure the provision for adequate intersection sight distance, on-site inspections should be conducted before and after construction, including placement of signs, lighting, guardrails, or other objects and how they impact intersection sight distance.

### C.9.b.3 Stopping Sight Distance

The provision for safe stopping sight distance at intersections and on turning roadways is even more critical than on open roadways. Vehicles are more likely to be traveling in excess of the design or posted speed and drivers are frequently distracted from maintaining a continuous view of the upcoming roadway.

#### C.9.b.3.(a) Approach to Stops

The approach to stop signs, yield signs, or traffic signals should be provided with a sight distance no less than values given in Table 3 – 17 Sight Distance for Approach to Stops. These values are applicable for any street, highway, or turning roadway. The driver should, at this required distance, have a clear view of the intersecting roadway, as well as the sign or traffic signal.

Where the approach roadway is on a grade or vertical curve, the sight distance should be no less than the values shown in Figure 3 – 10 Sight Distances for Approach to Stop on Grades. In any situation where it is feasible, sight distances exceeding those should be provided. This is desirable to allow for more gradual stopping maneuvers and to reduce the likelihood of vehicles running through stop signs or signals. Advance warnings for stop signs are desirable.

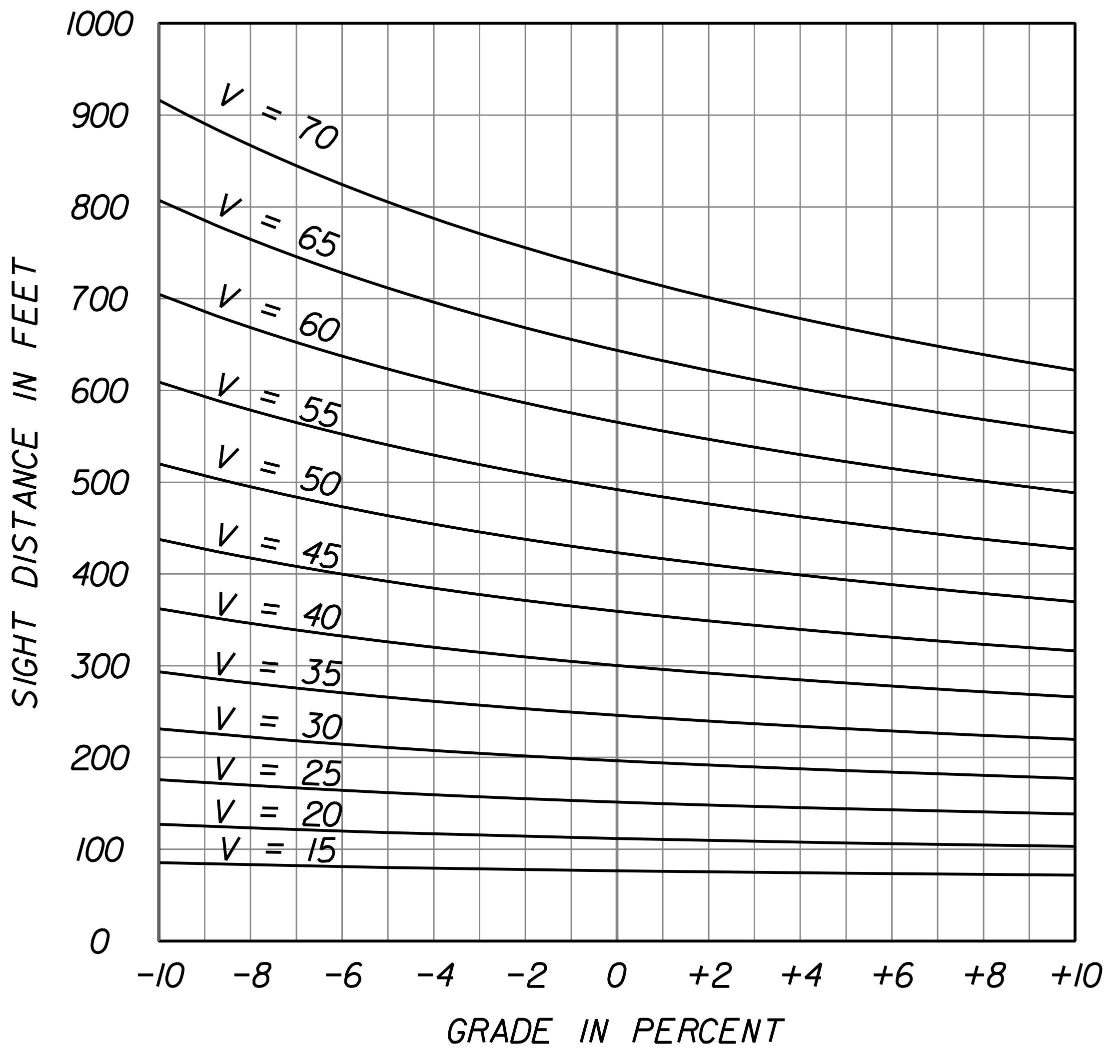
**Table 3 – 17**
**Sight Distance for Approach to Stops**
**(Rounded Values)**

| Design Speed (mph) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stopping Sight Distance (feet) (Minimum) | 115 | 155 | 200 | 250 | 305 | 360 | 425 | 495 | 570 | 645 | 730 |

#### C.9.b.3.(b) On Turning Roads

The required stopping sight distance at any location on a turning roadway (loop, exit, etc.) shall be based on the design speed at that point. Ample sight distance should be provided since the driver is burdened with negotiating a curved travel path and the available friction factor for stopping has been reduced by the roadway curvature. The minimum sight distance values are given in Table 3 – 17 or Figure 3 – 10. Due to the inability of vehicle headlights to adequately illuminate a sharply curved travel path, roadway lighting should be considered for turning roadways.

**Figure 3 – 10**
**Sight Distances for Approach to Stop on Grades**




$$S = 3.675V + \frac{V^2}{30(0.3478 \pm G)}$$

S = Sight Distance
V = Design Speed
G = Grade

### C.9.b.4 Sight Distance for Intersection Maneuvers

Sight distance is also provided at intersections to allow the drivers of stopped vehicles a sufficient view of the intersecting street or highway to decide when to enter or cross the intersecting street or highway. Sight triangles, which are specified areas along intersection approach legs and across their included corners, shall, where practical, be clear of obstructions that would prohibit a driver's view of potentially conflicting vehicles. Departure sight triangles shall be provided in each quadrant of each intersection approach controlled by stop signs.

Figures 3 – 11 Departure Sight Triangle (Traffic Approaching from Left or Right) and 3 – 12 Intersection Sight Distance show typical departure sight triangles to the left and to the right of the location of a stopped vehicle on a minor road (stop controlled) and the intersection sight distances for the various movements.

Distance "a" is the length of leg of the sight triangle along the minor road. This distance is measured from the driver's eye in the stopped vehicle to the center of the nearest lane on the major road (through road) for vehicles approaching from the left, and to the center of the nearest lane for vehicles approaching from the right.

Distance "b" is the length of the leg of the sight triangle along the major road measured from the center of the minor road entrance lane. This distance is a function of the design speed and the time gap in major road traffic needed for minor road drivers turning onto or crossing the major road. This distance is calculated as follows:

$$ISD = 1.47 V_{major} t_g$$

Where:

ISD=Intersection Sight Distance (ft.) – length of leg of sight triangle along the major road.

$V_{major}$= Design Speed (mph) of the Major Road

$t_g$= Time gap (sec.) for minor road vehicle to enter the major road.

Time gap values, $t_g$, to be used in determination of ISD are based on studies and observations of the time gaps in major road traffic actually accepted by drivers turning onto or across the major road. Design time gaps will vary and depend on the design vehicle, the type of the maneuver, the crossing distance involved in the maneuver, and the minor road approach grade.

For intersections with stop control on the minor road, there are three maneuvers or cases that must be considered. ISD is calculated for each maneuver case that may occur at the intersection. The case requiring the greatest ISD will control. Cases that must be considered are as follows (Case numbers correspond to cases identified in the ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011):***

Case B1 – Left Turns from the Minor (stop controlled) Road

Case B2 – Right Turns from the Minor (stop controlled) Road

Case B3 – Crossing the Major Road from the Minor (stop controlled) Road

See Sections C.9.b.4.(c) and (d) for design time gaps for Case B.

For Intersections with Traffic Signal Control see Section C.9.b.4.(e) (AASHTO Case D).

For intersections with all way stop control see Section C.9.b.4.(f) (AASHTO Case E).

For left turns from the major road see Section C.9.b.4.(g) (AASHTO Case F).

**Figure 3 – 11**
**Departure Sight Triangle**
**(Traffic Approaching from Left or Right)**

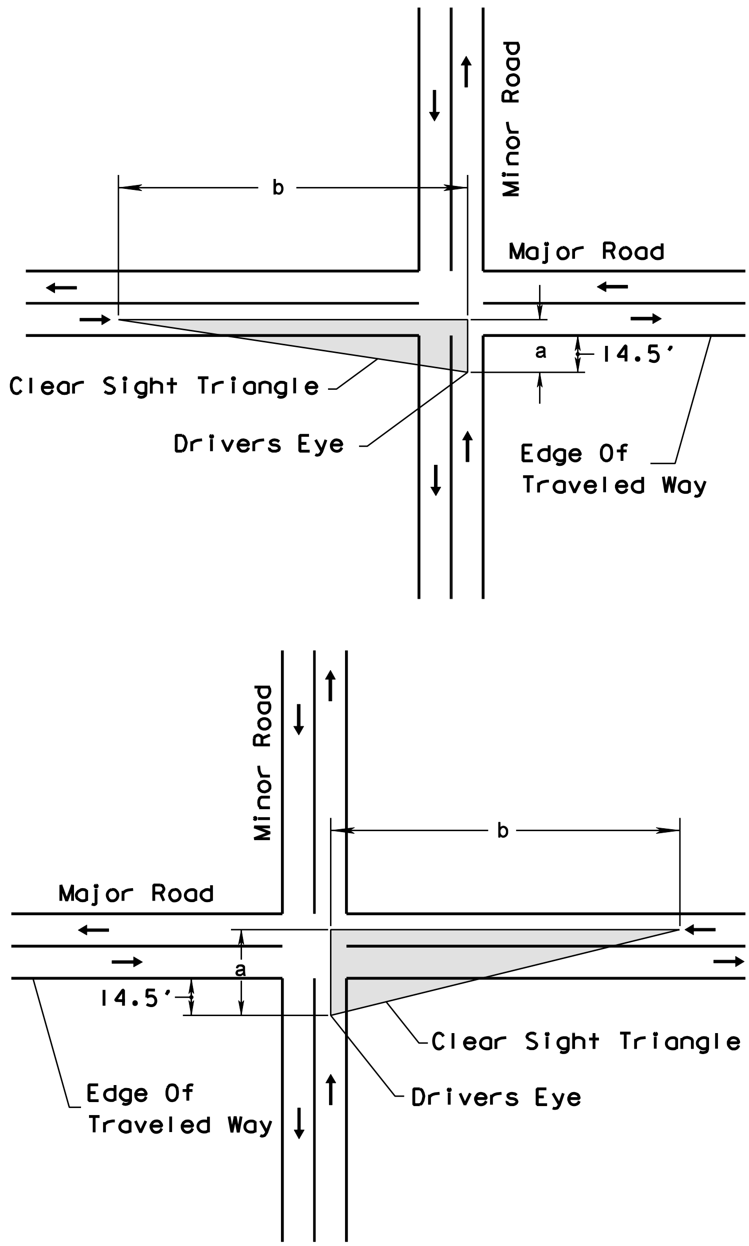
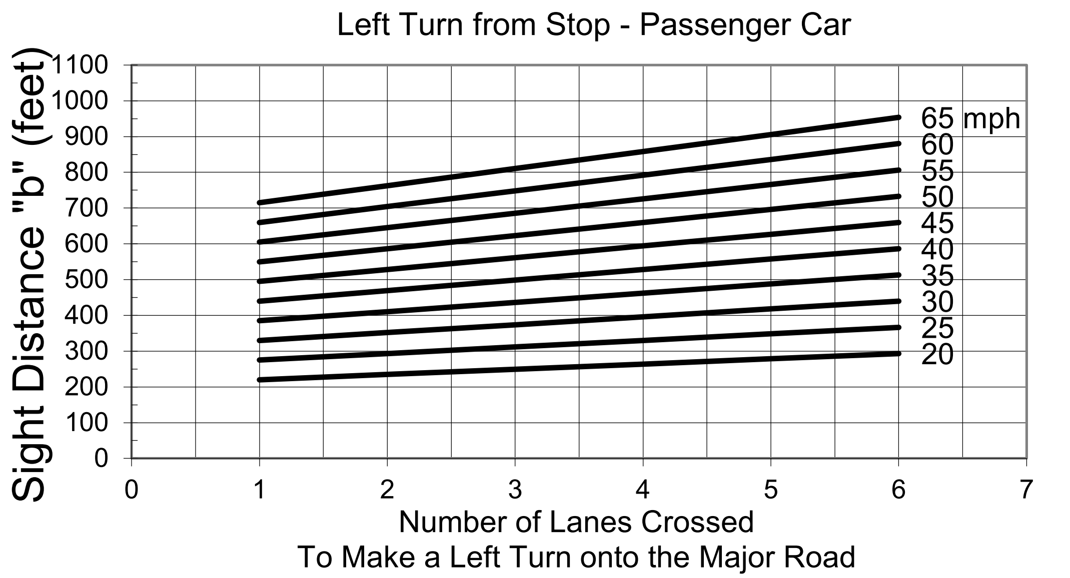
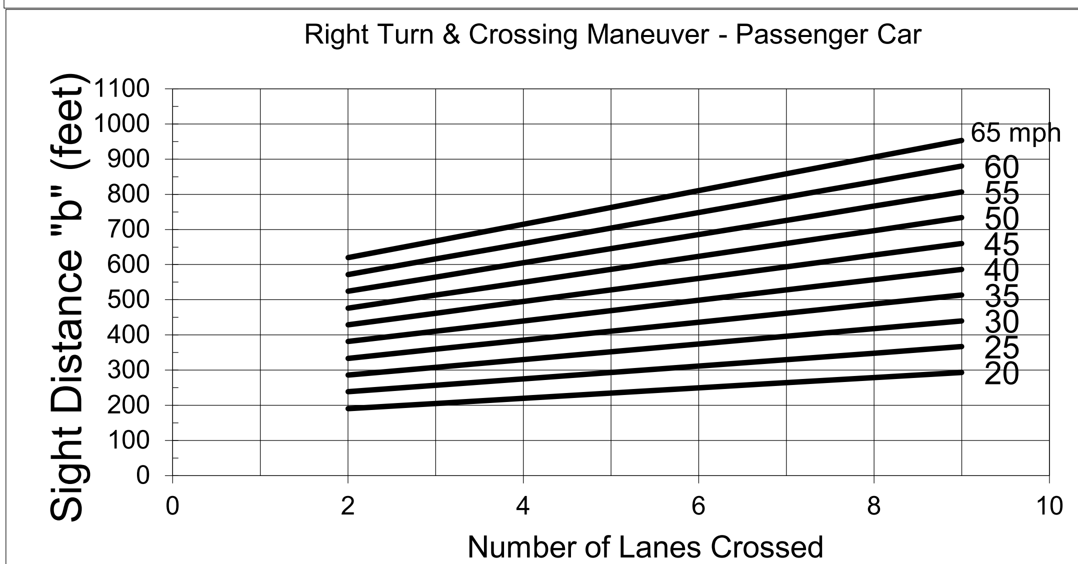


**Figure 3 – 12**
**Intersection Sight Distance**




A vehicle crosses one lane to make a left turn onto a two lane-two way road; crosses two lanes on a four lane undivided road; and so forth. For divided highways, convert median widths to equivalent number of lanes. For medians 25' and greater a two step maneuver may be considered - see text.




For right turn maneuver use distance based on 2 lanes crossed.
For crossing divided highways, convert median widths to equivalent number of lanes. For medians 25' and greater a two step maneuver may be considered - see text.

#### C.9.b.4.(a) Driver's Eye Position and Vehicle Stopping Position

The vertex (decision point or driver's eye position) of the departure sight triangle on the minor road shall be a minimum of 14.5 feet from the edge of the major road traveled way. This is based on observed measurements of vehicle stopping position and the distance from the front of the vehicle to the driver's eye. Field observations of vehicle stopping positions found that, where necessary, drivers will stop with the front of their vehicle 6.5 feet or less from the edge of the major road traveled way. Measurements of passenger cars indicate that the distance from the front of the vehicle to driver's eye for the current U.S. passenger car fleet is almost always 8 feet or less.

When executing a crossing or turning maneuver after stopping at a stop sign, stop bar, or crosswalk as required in ***Section 316.123, Florida Statutes***, it is assumed that the vehicle will move slowly forward to obtain sight distance (without intruding into the crossing travel lane) stopping a second time as necessary.

#### C.9.b.4.(b) Design Vehicle

Dimensions of clear sight triangles are provided for passenger cars, single unit trucks, and combination trucks stopped on the minor road. It can usually be assumed that the minor road vehicle is a passenger car. However, where substantial volumes of heavy vehicles enter the major road, such as from a ramp terminal, the use of tabulated values for single unit or combination trucks should be considered.

### C.9.b.4.(c) Case B1 - Left Turns From the Minor Road

Design time gap values for left turns from the minor road onto two lane two way major highway are as follows:

| Design Vehicle | Time Gap ($t_g$) in Seconds |
|---|---|
| Passenger Car | 7.5 |
| Single Unit Truck | 9.5 |
| Combination Truck | 11.5 |

If the minor road approach grade is an upgrade that exceeds 3 percent, add 0.2 seconds for each percent grade for left turns.

For multilane streets and highways without medians wide enough to store the design vehicle with a clearance of 3 feet on both ends of the vehicle, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane from the left, in excess of one, to be crossed by the turning vehicle. The median width should be included in the width of additional lanes. This is done by converting the median width to an equivalent number of 12 foot lanes.

For multilane streets and highways with medians wide enough to store the design vehicle with a clearance of 3 feet on both ends of the vehicle a two step maneuver may be assumed. Use case B2 for crossing to the median.

#### C.9.b.4.(d) Case B2 - Right Turns From the Minor Road and Case B3 – Crossing Maneuver from the Minor Road

Design time gap values for a stopped vehicle on a minor road to turn right onto or cross a two lane highway are as follows:

| Design Vehicle | Time Gap ($t_g$) in Seconds |
|---|---|
| Passenger Car | 6.5 |
| Single Unit Truck | 8.5 |
| Combination Truck | 10.5 |

If the approach grade is an upgrade that exceeds 3 percent, add 0.1 seconds for each percent grade.

For crossing streets and highways with more than 2 lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane to be crossed. Medians not wide enough to store the design vehicle with a clearance of 3 feet on both ends of the vehicle should be included in the width of additional lanes. This is done by converting the median width to an equivalent number of 12 foot lanes.

For crossing divided streets and highways with medians wide enough to store the design vehicle with a clearance of 3 feet on both ends of the vehicle, a two step maneuver may be assumed. Only the number of lanes to be crossed in each step are considered.

#### C.9.b.4.(e) Intersections with Traffic Signal Control (AASHTO Case D)

At signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. Left turning vehicles should have sufficient sight distance to select gaps in oncoming traffic and complete left turns. Apart from these sight conditions, no other sight triangles are needed for signalized intersections. However, if the traffic signal is to be placed on two-way flashing operation in off peak or nighttime conditions, then the appropriate departure sight triangles for Cases B1, B2, or B3, both to the left and to the right, should be provided. In addition, if right turns on red are to be permitted, then the appropriate departure sight triangle to the left for Case B2 should be provided to accommodate right turns.

#### C.9.b.4.(f) Intersections with All-Way Stop Control (AASHTO Case E)

At intersections with all-way stop control, the first stopped vehicle on one approach should be visible to the drivers of the first stopped vehicles on each of the other approaches. There are no other sight distance criteria applicable to intersections with all-way stop control.

#### C.9.b.4.(g) Left Turns from the Major Road (AASHTO Case F)

All locations along a major road from which vehicles are permitted to turn left across opposing traffic shall have sufficient sight distance to accommodate the left turn maneuver. In this case, the ISD is measured from the stopped position of the left turning vehicle (see Figure 3 – 13 Sight Distance for Vehicle Turning Left from Major Road).

Design time gap values for left turns from the major road are as follows:

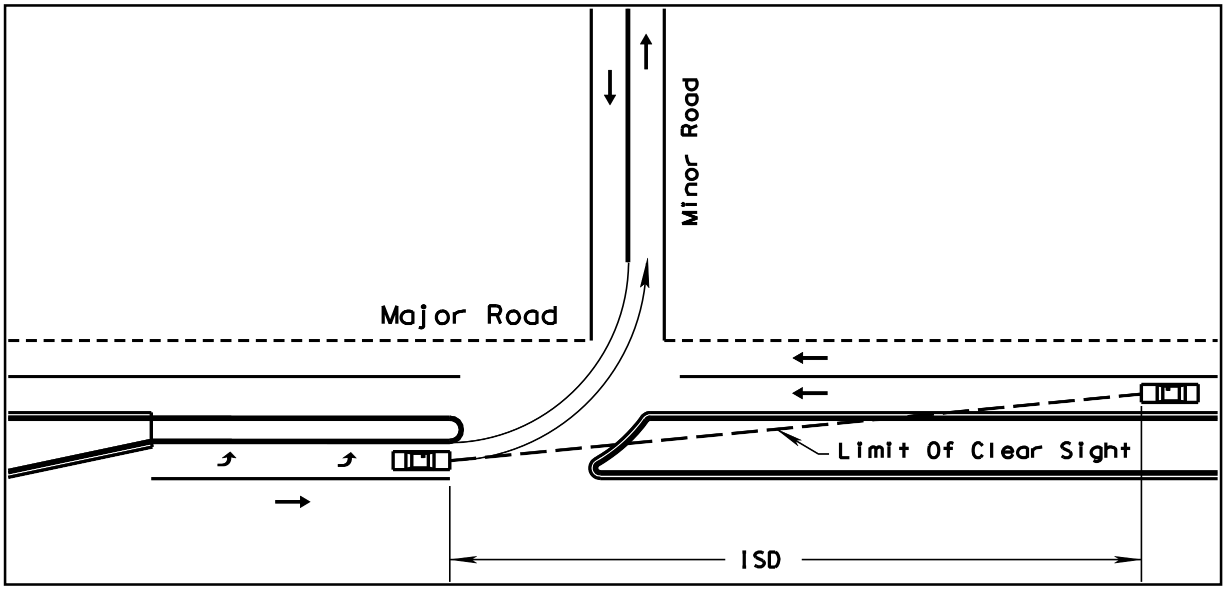
| Design Vehicle | Time Gap ($t_g$) in Seconds |
|---|---|
| Passenger Car | 5.5 |
| Single Unit Truck | 6.5 |
| Combination Truck | 7.5 |

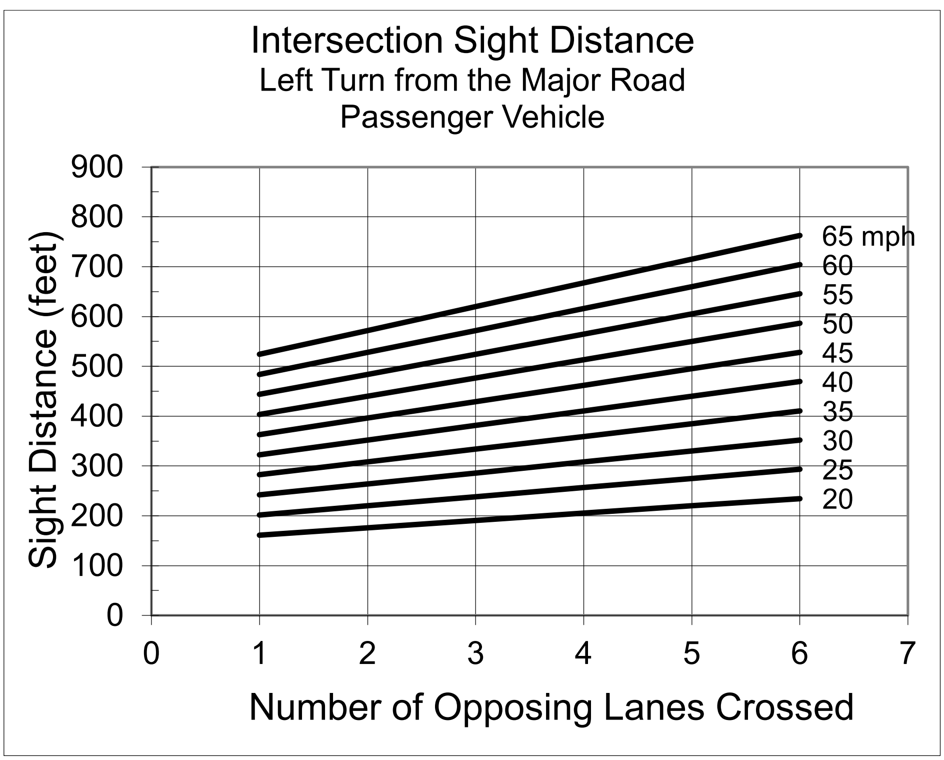
For left turning vehicles that cross more than one opposing lane, add 0.5 seconds for passenger cars and 0.7 seconds for trucks for each additional lane to be crossed.

#### C.9.b.4.(h) Intersection Sight Distance References

The Department's ***Design Standards, Index 546***, provides ISD values for several basic intersection configurations based on Cases B1, B2, B3, and D, and may be used when applicable. For additional guidance on Intersection Sight Distance, see ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***.

**Figure 3 – 13**
**Sight Distance for Vehicle Turning Left from Major Road**



### C.9.c Auxiliary Lanes

Auxiliary lanes are desirable for the safe execution of speed change maneuvers (acceleration and deceleration) and for the storage and protection of turning vehicles. Auxiliary lanes for exit or entrance turning maneuvers shall be provided in accordance with the requirements set forth in C.8 Access Control, this chapter. The pavement width and cross slopes of auxiliary lanes should meet the minimum requirements shown in Table 3 – 10 Minimum Lane Widths.

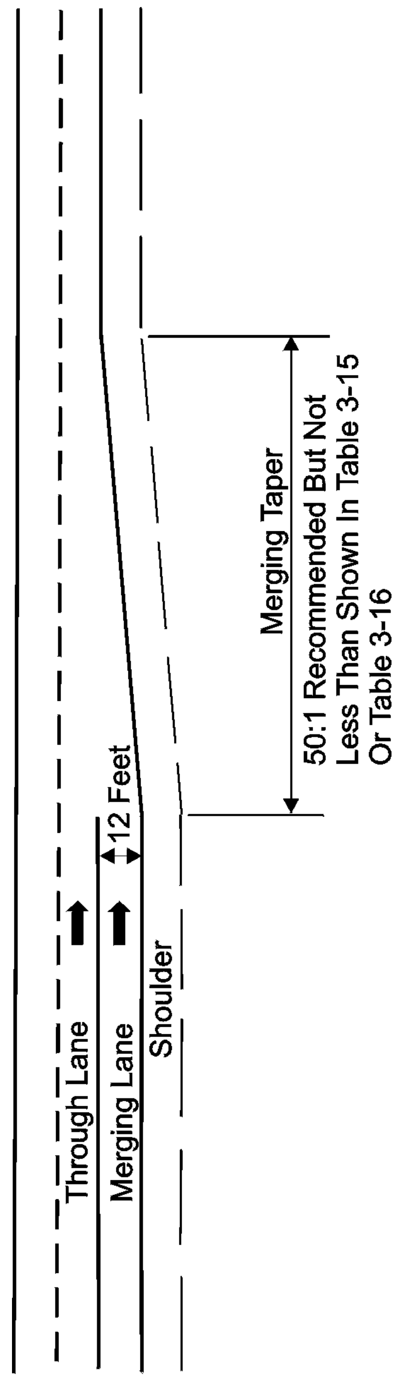
#### C.9.c.1 Merging Maneuvers

Merging maneuvers occur at the termination of climbing lanes, lane drops, entrance acceleration, and turning lanes. The location provided for this merging maneuver should, where possible, be on a tangent section of the roadway and should be of sufficient length to allow for a smooth, safe transition. The provision of ample distance for merging is essential to allow the driver time to find an acceptable gap in the through traffic and then execute a safe merging maneuver. It is recommended that a merging taper be on a 1:50 transition, but in no case shall the length be less than set forth in Table 3 – 18 Length of Taper for Use In Conditions With Full Width Speed Change Lanes. The termination of this lane should be clearly visible from both the merging and through lane and should correspond to the general configuration shown in Figure 3 – 14 Termination of Merging Lanes. Advance warning of the merging lane termination should be provided. Lane drops shall be marked in accordance with ***Section 14-15.010, F.A.C. Manual on Uniform Traffic Control Devices (MUTCD)***.

**Table 3 – 18**
**Length of Taper for Use in Conditions**
**With Full Width Speed Change Lanes**

| Design Speed (mph) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Length of Deceleration Taper (feet) | 110 | 130 | 150 | 170 | 190 | 210 | 230 | 250 | 270 | 290 | 300 |
| Length of Acceleration Taper (feet) | 80 | 100 | 120 | 140 | 160 | 180 | 210 | 230 | 250 | 260 | 280 |

**Figure 3 – 14**
**Termination of Merging Lanes**



#### C.9.c.2 Acceleration Lanes

Acceleration lanes are required for all entrances to expressway and freeway ramps. Acceleration lanes may be desirable at access points to any street or highway with a large percentage of entering truck traffic.

The distance required for an acceleration maneuver is dependent on the vehicle acceleration capabilities, the grade, the initial entrance speed, and the final speed at the termination of the maneuver. The distances required for acceleration on level roadways for passenger cars are given in Table 3 – 19 Design Lengths of Speed Change Lanes Flat Grades. Where acceleration occurs on a grade, the required distance is obtained by using Tables 3 – 19 and 3 – 20 Ratio of Length of Speed Change Lane on Grade to Length on Level.

The final speed at the end of the acceleration lane, should, desirably, be assumed as the design speed of the through roadway. The length of acceleration lane provided should be at least as long as the distance required for acceleration between the initial and final speeds. Due to the uncertainties regarding vehicle capabilities and driver behavior, additional length is desirable. The acceleration lane should be followed by a merging taper (similar to Figure 3 – 14 Termination of Merging Lanes), not less than that length set forth in Table 3 – 18. The termination of acceleration lanes should conform to the general configuration shown for merging lanes in Figure 3 – 14. Recommended acceleration lanes for freeway entrance terminals are given in Table 3 – 21 Minimum Acceleration Lengths for Entrance Terminals.

## Table 3 – 19
## Design Lengths of Speed Change Lanes
## Flat Grades - 2 Percent or Less

| Design Speed of turning roadway curve (mph) | | Stop Condition | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|
| Minimum curve radius (feet) | | --- | 100 | 160 | 230 | 320 | 430 | 555 | 695 |
| Design Speed of Highway (mph) | Length of Taper (feet)* | Total length of DECELERATION LANE, including taper, (feet) | | | | | | | |
| 30 | 150 | 385 | 320 | 290 | --- | --- | --- | --- | --- |
| 35 | 170 | 450 | 380 | 355 | 320 | --- | --- | --- | --- |
| 40 | 190 | 510 | 455 | 425 | 375 | 345 | --- | --- | --- |
| 45 | 210 | 595 | 535 | 505 | 460 | 430 | --- | --- | --- |
| 50 | 230 | 665 | 615 | 585 | 545 | 515 | 455 | 405 | --- |
| 55 | 250 | 730 | 690 | 660 | 630 | 600 | 535 | 485 | --- |
| 60 | 270 | 800 | 750 | 730 | 700 | 675 | 620 | 570 | 510 |
| 65 | 290 | 860 | 810 | 790 | 760 | 730 | 680 | 630 | 570 |
| 70 | 300 | 915 | 870 | 850 | 820 | 790 | 740 | 690 | 640 |
| Design Speed of Highway (mph) | Length of Taper (feet)* | Total length of ACCELERATION LANE, including taper (feet) | | | | | | | |
| 30 | 120 | 300 | --- | --- | --- | --- | --- | --- | --- |
| 35 | 140 | 420 | 300 | --- | --- | --- | --- | --- | --- |
| 40 | 160 | 520 | 430 | 370 | 280 | --- | --- | --- | --- |
| 45 | 180 | 740 | 620 | 560 | 460 | 340 | --- | --- | --- |
| 50 | 210 | 930 | 820 | 760 | 660 | 560 | 340 | --- | --- |
| 55 | 230 | 1190 | 1040 | 1010 | 900 | 780 | 550 | 380 | --- |
| 60 | 250 | 1450 | 1350 | 1270 | 1160 | 1050 | 800 | 670 | 430 |
| 65 | 260 | 1670 | 1570 | 1480 | 1380 | 1260 | 1030 | 860 | 630 |
| 70 | 280 | 1900 | 1800 | 1700 | 1630 | 1510 | 1280 | 1100 | 860 |

* For urban street auxiliary lanes, shorter tapers may be used due to lower operating speeds. Refer to Figure 3 – 16 for allowable taper rates.

## Table 3 – 20
## Ratio of Length of Speed Change Lane on Grade to Length on Level

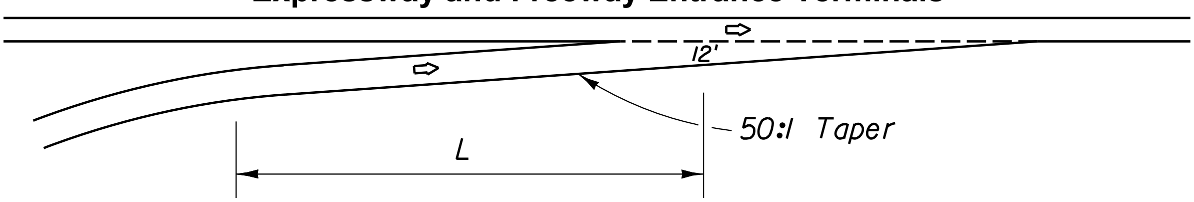
| Deceleration Lane | | | Acceleration Lane | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Design Speed of Turning Roadway (mph) | | | Design Speed of Turning Roadway (mph) | | | | |
| Design Speed of Highway (mph) | All Speeds<br>3% - 4% Upgrade | All Speeds<br>3% - 4% Downgrade | Design Speed of Highway (mph) | 20<br>3% - 4% Upgrade | 30 | 40 | 50 | All Speeds<br>3% - 4% Downgrade |
| All Speeds | 0.9 | 1.2 | 40 | 1.3 | 1.3 | --- | --- | 0.7 |
| | | | 45 | 1.3 | 1.35 | --- | --- | 0.675 |
| | | | 50 | 1.3 | 1.4 | 1.4 | --- | 0.65 |
| | | | 55 | 1.35 | 1.45 | 1.45 | --- | 0.625 |
| | | | 60 | 1.4 | 1.5 | 1.5 | 1.6 | 0.6 |
| | | | 65 | 1.45 | 1.55 | 1.6 | 1.7 | 0.6 |
| | | | 70 | 1.5 | 1.6 | 1.7 | 1.8 | 0.6 |
| | 5% - 6% Upgrade | 5% - 6% Downgrade | | 5% - 6% Upgrade | | | | 5% - 6% Downgrade |
| All Speeds | 0.8 | 1.35 | 40 | 1.5 | 1.5 | --- | --- | 0.6 |
| | | | 45 | 1.5 | 1.6 | --- | --- | 0.575 |
| | | | 50 | 1.5 | 1.7 | 1.9 | --- | 0.55 |
| | | | 55 | 1.6 | 1.8 | 2.05 | --- | 0.525 |
| | | | 60 | 1.7 | 1.9 | 2.2 | 2.5 | 0.5 |
| | | | 65 | 1.85 | 2.05 | 2.4 | 2.75 | 0.5 |
| | | | 70 | 2.0 | 2.2 | 2.6 | 3.0 | 0.5 |

Ratios in this table multiplied by the values in Table 3 – 18 give the length of speed change lane for the respective grade.

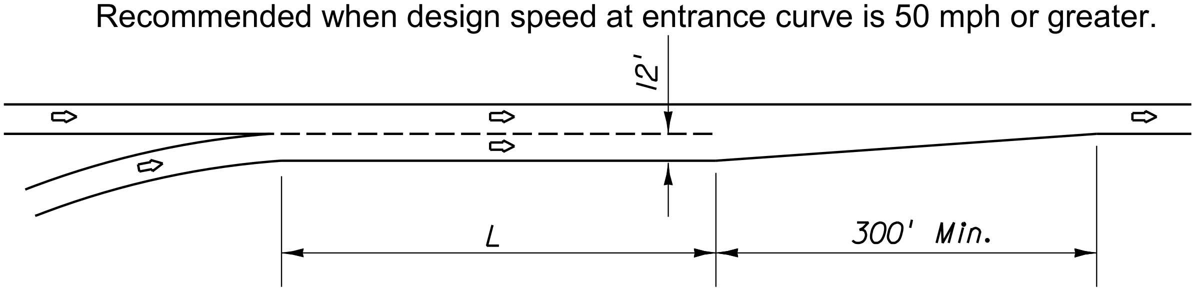
**Table 3 – 21**
**Minimum Acceleration Lengths for Entrance Terminals**

| Highway Design Speed (mph) | L = Acceleration Length (feet) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | For Entrance Curve Design Speed (mph) | | | | | | | |
| | Stop Condition | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 30 | 180 | --- | --- | --- | --- | --- | --- | --- |
| 35 | 280 | 160 | --- | --- | --- | --- | --- | --- |
| 40 | 360 | 270 | 210 | 120 | --- | --- | --- | --- |
| 45 | 560 | 440 | 380 | 280 | 160 | --- | --- | --- |
| 50 | 720 | 610 | 550 | 450 | 350 | 130 | --- | --- |
| 55 | 960 | 810 | 780 | 670 | 550 | 320 | 150 | --- |
| 60 | 1200 | 1100 | 1020 | 910 | 800 | 550 | 420 | 180 |
| 65 | 1410 | 1310 | 1220 | 1120 | 1000 | 770 | 600 | 370 |
| 70 | 1620 | 1520 | 1420 | 1350 | 1,230 | 1000 | 820 | 580 |

**Expressway and Freeway Entrance Terminals**




TAPER TYPE
Recommended when design speed at entrance curve is 50 mph or greater.




PARALLEL TYPE
Recommended when design speed at entrance curve is less than 50 mph.

#### C.9.c.3 Exit Lanes

Auxiliary lanes for exiting maneuvers provide space outside the through lanes for protection and storage of decelerating vehicles exiting the facility.

- Deceleration Lanes - The primary function of deceleration lanes is to provide a safe travel path for vehicles decelerating from the operating speed on the through lanes. Deceleration lanes are required for all freeway exits and are desirable on high-speed (design speed greater than 50 mph) streets and highways.

The distance required for deceleration of passenger cars is given in Table 3 – 19.

The required distance for deceleration on grades is given in Tables 3 – 19 and 3 – 20.

The length of deceleration lanes shall be no less than the values obtained from Tables 3 – 19 and 3 – 20, and should be increased wherever feasible. The initial speed should, desirably, be taken as the design speed of the highway. The final speed should be the design speed at the exit (e.g., a turning roadway) or zero, if the deceleration lane terminates at a stop or traffic signal. A reduction in the final speed to be used is particularly important if the exit traffic volume is high, since the speed of these vehicles may be significantly reduced.

The entrance to deceleration (and climbing) lanes should conform to the general configuration shown in Figure 3 – 15 Entrance for Deceleration Lane. The initial length of straight taper, shown in Table 3 – 19, may be utilized as a portion of the total required deceleration distance. The pavement surface of the deceleration lane should be clearly visible to approaching traffic, so drivers are aware of the maneuvers required. Recommended deceleration lanes for exit terminals are given in Table 3 – 22 Minimum Deceleration Lengths for Exit Terminals.

- Storage Lanes - Where exit lanes are required (***Section C.8 Access Control***, this chapter), or desirable on low speed streets and highways, storage lanes may be used in place of or in conjunction with deceleration lanes. Storage lanes should be considered on all facilities. Although the primary function of storage lanes is to provide protection and storage for turning vehicles, it is desirable to provide sufficient length to allow for deceleration capabilities. Storage lanes should conform to the general configuration shown in Figure 3 – 16 Typical Storage Lane.

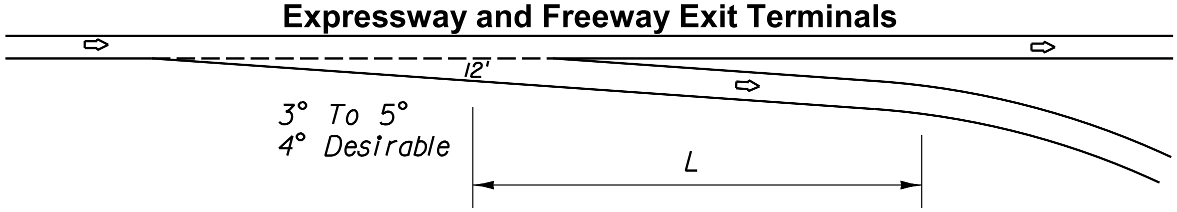
The length of storage lanes for unsignalized intersections may be obtained from the table in Figure 3 – 16. The full width portion of storage lanes should, where possible, be increased to allow for expected storage of vehicles (Table 3 – 2 for vehicle lengths). As a minimum requirement, storage for at least two passenger cars (40 - 50 feet) should be provided.

On collector or arterial streets (design speed 45 mph or less), tapers preceding storage lanes and approaching intersections at grade may be shorter than those given in Table 3 – 19. (See ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)*** for recommended lengths).

**Table 3 – 22**
**Minimum Deceleration Lengths for Exit Terminals**

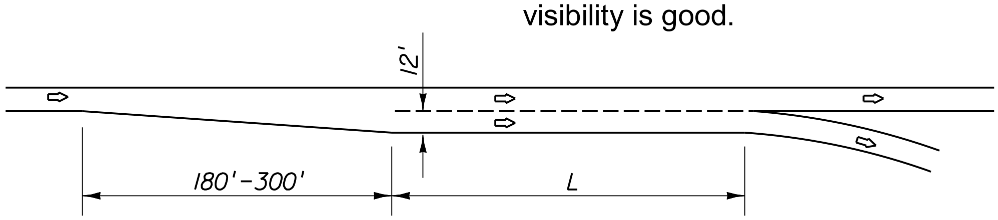
| Highway Design Speed (mph) | L = Deceleration Length (feet) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | For Design Speed of Exit Curve (mph) | | | | | | | |
| | Stop Condition | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 30 | 235 | 170 | 140 | --- | --- | --- | --- | --- |
| 35 | 280 | 210 | 185 | 150 | --- | --- | --- | --- |
| 40 | 320 | 265 | 235 | 185 | 155 | --- | --- | --- |
| 45 | 385 | 325 | 295 | 250 | 220 | --- | --- | --- |
| 50 | 435 | 385 | 355 | 315 | 285 | 225 | 175 | --- |
| 55 | 480 | 440 | 410 | 380 | 350 | 285 | 235 | --- |
| 60 | 530 | 480 | 460 | 430 | 405 | 350 | 300 | 240 |
| 65 | 570 | 520 | 500 | 470 | 440 | 390 | 340 | 280 |
| 70 | 615 | 570 | 550 | 520 | 490 | 440 | 390 | 340 |

## Expressway and Freeway Exit Terminals




*TAPER TYPE*

Recommended when design speed at exit curve is 50 mph or greater and when approach visibility is good.




*PARALLEL TYPE*

Recommended when design speed at exit curve is less than 50 mph or when approach visibility is not good.

**Figure 3 – 15**
**Entrance for Deceleration Lane**

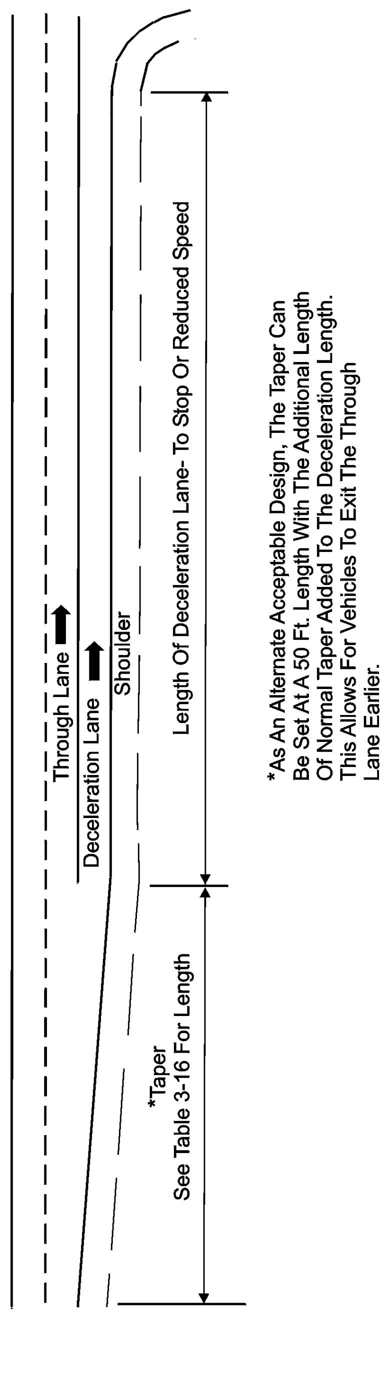
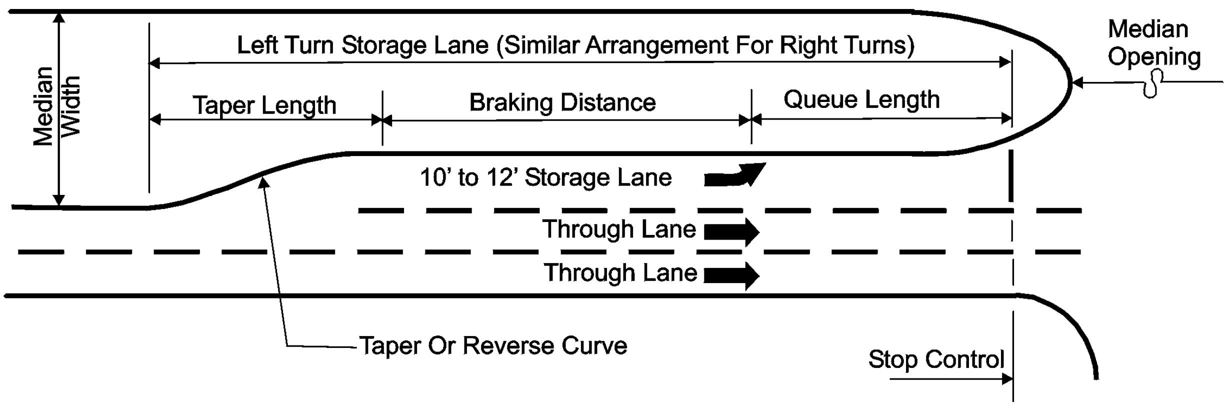


**Figure 3 – 16**
**Typical Storage Lane**




**Storage Queue Length - Unsignalized Intersections**

| | | | | | |
|---|---|---|---|---|---|
| Turning Vehicles Per Hour | 30 | 60 | 100 | 200 | 300 |
| Required Storage Length (feet) | 25 | 50 | 100 | 175 | 250 |

At signalized intersections, the required queue length depends on the signal cycle length, the signal phasing arrangement, and rate of arrivals and departures of turning vehicles.

In absence of a turning movement study, it is recommended that 100 ft. of queue length be provided in urban/suburban areas and 50 ft. of queue length be provided in rural/town areas as a minimum.

**Taper Length And Braking Distance (feet)**

| **Highway Design Speed (mph)** | **Storage Entry Speed* (mph)** | **Taper Length** | **Brake To Stop** | |
|---|---|---|---|---|
| | | | **Urban**** | **Rural***** |
| 35 | 25 | 70 | 75 | --- |
| 40 | 30 | 80 | 75 | --- |
| 45 | 35 | 85 | 100 | --- |
| 50 | 40/44 | 105 | 135 | 215 |
| 55 | 48 | 125 | --- | 260 |
| 60 | 52 | 145 | --- | 310 |
| 65 | 55 | 170 | --- | 350 |

* Reaction Precedes Entry
** Minimum Braking Distance, Wet Conditions
*** Customary Braking Distance, Wet Conditions

The storage lane may be in place of or in addition to deceleration length (See Section C.9.c.3).

### C.9.d Turning Roadways at Intersections

The design and construction of turning roadways shall meet the same general requirements for through roadways, except for the specific requirements given in the subsequent sections.

#### C.9.d.1 Design Speed

Lanes for turning movements at grade intersections may, where justified, be based on a design speed as low as 10 mph. Turning roadways with design speeds in excess of 40 mph shall be designed in accordance with the requirements for through roadways.

A variable design speed may be used to establish cross section and alignment criteria for turning roadways that will experience acceleration and deceleration maneuvers.

#### C.9.d.2 Horizontal Alignment

- Curvature - The minimum permitted radii (maximum degree) of curvature for various values of superelevation are given in Table 3 – 23 Superelevation Rates for Curves at Intersections. These should be considered as minimum values only and the radius of curvature should be increased wherever feasible. Further information contained in ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***, should also be considered.

**Table 3 – 23**
**Superelevation Rates for Curves at Intersections**

| | Design Speed (mph) | | | | | |
|---|---|---|---|---|---|---|
| | **20** | **25** | **30** | **35** | **40** | **45** |
| Minimum Superelevation Rate | 0.02 | 0.04 | 0.06 | 0.08 | 0.09 | 0.10 |
| Minimum Radius (feet) | 90 | 150 | 230 | 310 | 430 | 540 |

The rate of 0.02 is considered the practical minimum for effective drainage across the surface.

Note: Preferably use superelevation rates greater than these minimum values.

- Superelevation Transition - Minimum superelevation transition (runoff) rates (maximum relative gradients) are given in Tables 3 – 24 Maximum Rate of Change in Pavement Edge Elevation for Curves at Intersections and 3 – 25 Maximum Algebraic Difference in Pavement Cross Slope at Turning Roadway Terminals. Other information given in ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***, should also be considered.

**Table 3 – 24**
**Maximum Rate of Change in Pavement Edge Elevation for Curves at Intersections**

| Design Speed (mph) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum relative gradients for profiles between the edge of two lane pavement and the centerline (percent) | 0.74 | 0.70 | 0.66 | 0.62 | 0.58 | 0.54 | 0.50 | 0.47 | 0.45 | 0.43 | 0.40 |

**Table 3 – 25**
**Maximum Algebraic Difference in Pavement Cross Slope at Turning Roadway Terminals**

| Design Speed of Exit or Entrance Curve (mph) | Maximum Algebraic Difference in Cross Slope at Crossover Line (percent) |
|---|---|
| 20 and under | 5.0 to 8.0 |
| 25 and 30 | 5.0 to 6.0 |
| 35 and over | 4.0 to 5.0 |

### C.9.d.3 Vertical Alignment

Grades on turning roadways should be as flat as practical and long vertical curves should be used wherever feasible. The length of vertical curves shall be no less than necessary to provide minimum stopping sight distance. Minimum stopping sight distance values are given in Table 3 – 17. For additional guidance on vertical alignment for turning roadways, see ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***.

### C.9.d.4 Cross Section Elements

- Number of Lanes - One-way turning roadways are often limited to a single traffic lane. In this case, the total width of the roadway shall be sufficient to allow traffic to pass a disabled vehicle. Two-way, undivided turning roadways should be avoided. Medians or barriers should be utilized to separate opposing traffic on turning roadways.
- Lane Width - The width of all traffic lanes should be sufficient to accommodate (with adequate clearances) the turning movements of the expected types of vehicles. The minimum required lane widths for turning roadways are given in Table 3 – 26 Derived Pavement Widths for Turning Roadways for Different Design Vehicles. Changes in lane widths should be gradual and should be accomplished in coordination with adequate transitions in horizontal curvature.

- Shoulders - On one-lane turning roadways, serving expressways and other arterials (e.g., loops, ramps), the right hand shoulder should be at least 6 feet wide. The left hand shoulder should be at least 6 feet wide in all cases. On two-lane, one-way roadways, both shoulders should be at least 6 feet wide. Where guardrails or other barriers are used, they should be placed at least 8 feet from edge of travel lane. Guardrails should be placed 2 feet outside the normal shoulder width.
- Clear Zones - Turning roadways should, as a minimum, meet all open highway criteria for clear zones on both sides of the roadway. The areas on the outside of curves should be wider and more gently sloped than the minimum values for open highways. Guardrails or similar barriers shall be used if the minimum width and slope requirements cannot be obtained.

Further criteria and requirements for roadway design are given in ***Chapter 4 – Roadside Design***.

## Table 3 – 26
## Derived Pavement Widths for Turning Roadways for Different Design Vehicles

| Radius on Inner Edge of Pavement, R (feet) | Case 1, One-Lane Operation, No Provision for Passing a Stalled Vehicle | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | SU-30 | Su-40 | City Bus | S-Bus-36 | A-Bus | WB-40 | WB-62 | WB-67 | WB-67D | MH | P/T | P/B |
| 50 | 13 | 18 | 21 | 21 | 18 | 22 | 23 | 44 | 57 | 29 | 18 | 19 | 18 |
| 75 | 13 | 17 | 18 | 19 | 17 | 19 | 20 | 30 | 33 | 23 | 17 | 17 | 17 |
| 100 | 13 | 16 | 17 | 18 | 16 | 18 | 18 | 25 | 28 | 21 | 16 | 16 | 16 |
| 150 | 12 | 15 | 16 | 17 | 16 | 17 | 17 | 22 | 23 | 19 | 15 | 16 | 15 |
| 200 | 12 | 15 | 16 | 16 | 15 | 16 | 16 | 20 | 21 | 18 | 15 | 15 | 15 |
| 300 | 12 | 15 | 15 | 16 | 15 | 16 | 15 | 18 | 19 | 17 | 15 | 15 | 15 |
| 400 | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 17 | 18 | 16 | 15 | 15 | 14 |
| 500 | 12 | 14 | 15 | 15 | 14 | 15 | 15 | 17 | 17 | 16 | 14 | 14 | 14 |
| Target | 12 | 14 | 14 | 15 | 14 | 15 | 14 | 15 | 15 | 15 | 14 | 14 | 14 |
| | | | | | | | | | | | | | |

| Radius on Inner Edge of Pavement, R (feet) | Case II, One-Lane, One-Way Operation, with Provision for Passing a Stalled Vehicle by Another of the Same Type | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | SU-30 | SU-40 | City Bus | S-Bus-36 | A-Bus | WB-40 | WB-62 | WB-67 | WB-67D | MH | P/T | P/B |
| 50 | 20 | 30 | 36 | 38 | 31 | 40 | 39 | 81 | 109 | 50 | 30 | 30 | 28 |
| 75 | 19 | 27 | 30 | 32 | 27 | 34 | 32 | 53 | 59 | 39 | 27 | 27 | 26 |
| 100 | 18 | 25 | 27 | 30 | 25 | 30 | 29 | 44 | 48 | 34 | 25 | 25 | 24 |
| 150 | 18 | 23 | 25 | 27 | 23 | 27 | 26 | 36 | 38 | 29 | 23 | 23 | 23 |
| 200 | 17 | 22 | 24 | 25 | 23 | 26 | 24 | 32 | 34 | 27 | 22 | 22 | 22 |
| 300 | 17 | 22 | 22 | 24 | 22 | 24 | 23 | 28 | 30 | 25 | 22 | 22 | 21 |
| 400 | 17 | 21 | 22 | 23 | 21 | 23 | 22 | 26 | 27 | 24 | 21 | 21 | 21 |
| 500 | 17 | 21 | 21 | 23 | 21 | 23 | 22 | 25 | 26 | 23 | 21 | 21 | 21 |
| Target | 17 | 20 | 20 | 21 | 20 | 21 | 20 | 21 | 21 | 21 | 20 | 20 | 20 |

Table Continued on Next Page

| **Radius on Inner Edge of Pavement, R (feet)** | **Case III, Two-Lane Operation, Either One- or Two-Way (Same Type Vehicle in Both Lanes)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | SU-30 | SU-40 | City Bus | S-Bus-36 | A-Bus | WB-40 | WB-62 | WB-67 | WB-67D | MH | P/T | P/B |
| 50 | 26 | 36 | 42 | 44 | 37 | 46 | 45 | 87 | 115 | 56 | 36 | 36 | 34 |
| 75 | 25 | 33 | 36 | 38 | 33 | 40 | 38 | 59 | 65 | 45 | 33 | 33 | 32 |
| 100 | 24 | 31 | 33 | 35 | 31 | 36 | 35 | 50 | 54 | 40 | 31 | 31 | 30 |
| 150 | 24 | 29 | 31 | 33 | 29 | 33 | 32 | 42 | 44 | 35 | 29 | 29 | 29 |
| 200 | 23 | 28 | 30 | 31 | 29 | 32 | 30 | 38 | 40 | 33 | 28 | 28 | 28 |
| 300 | 23 | 28 | 28 | 30 | 28 | 30 | 29 | 34 | 36 | 31 | 28 | 28 | 27 |
| 400 | 23 | 27 | 28 | 29 | 27 | 29 | 28 | 32 | 33 | 30 | 27 | 27 | 27 |
| 500 | 23 | 27 | 27 | 29 | 27 | 29 | 28 | 31 | 32 | 29 | 27 | 27 | 27 |
| Target | 23 | 26 | 26 | 27 | 26 | 27 | 28 | 27 | 27 | 27 | 26 | 26 | 26 |

Source – 2011 AASHTO Greenbook, Table 3 - 28b Derived Pavement Widths for Turning Roadways for Different Design Vehicle

### C.9.e At Grade Intersections

#### C.9.e.1 Turning Radii

Where right turns from through or turn lanes will be negotiated at low speeds (less than 10 mph), the minimum turning capabilities of the vehicle may govern the design. It is desirable that the turning radius and the required lane width be provided in accordance with the criteria for turning roadways. The radius of the inside edge of traveled way should be sufficient to allow the expected vehicles to negotiate the turn without encroaching the shoulder or adjacent traffic lanes.

Where turning roadway criteria are not used, the radius of the inside edge of traveled way should be no less than 25 feet. The use of three-centered compound curves is also a reasonable practice to allow for transition into and out of the curve. The recommended radii and arrangement of compound curves instead of a single simple curve is given in ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***.

#### C.9.e.2 Cross Section Correlation

The correlation of the cross section of two intersecting roadways is frequently difficult. A careful analysis should be conducted to ensure changes in slope are not excessive and adequate drainage is provided. At stop-controlled intersections, the through roadway cross section should be carried through the intersection without interruption. Minor roadways should approach the intersection at a slightly reduced elevation so the through roadway cross section is not disturbed. At signalized intersections, it is sometimes necessary to remove part of the crown in order to avoid an undesirable hump in one roadway.

Intersections of grade or cross slope should be gently rounded to improve vehicle operation. Pavement generally should be sloped toward the intersection corners to provide superelevation for turning maneuvers and to promote proper drainage.

Where islands are used for channelization, the width of traffic lanes for turning movements shall be no less than the widths recommended by AASHTO.

#### C.9.e.3 Median Openings

Median openings should be restricted in accordance with the requirements presented in ***Section C.8 Access Control***, this chapter. Where a median opening is required, the length of the opening shall be no less than 40 feet. Median curbs should be terminated gradually without the exposure of abrupt curb ends. The termination requirements are given in ***Chapter 4 – Roadside Design***.

#### C.9.e.4 Channelization

Channelization of at grade intersections is the regulation or separation of conflicting movements into definite travel paths by islands, markings, or other means, to promote safe, orderly traffic flow. The major objective of channelization is to clearly define the appropriate paths of travel and thus assist in the prevention of vehicles deviating excessively or making wrong maneuvers. Channelization may be used effectively to define the proper path for exits, entrances, and intersection turning movements. The methods used for channelization should be as simple as possible and consistent in nature. The channelized intersection should appear open and natural to the approaching driver. Channelization should be informative rather than restrictive in nature.

The use of low sloping curbs and flush medians and islands can provide adequate delineation in most cases. Islands should be clearly visible and, in general, should not be smaller than 100 square feet in area. The use of small and/or numerous islands should be avoided.

Pavement markings are a useful and effective tool for providing delineation and channelization in an informative rather than restrictive fashion. The layout of all traffic control devices should be closely coordinated with the design of all channelization.

### C.9.f Driveways

Direct driveway access within the area of influence of the intersection should be discouraged.

Driveways from major traffic generators (greater than 400 vpd), or those with significant truck/bus traffic, should be designed as normal intersections.

### C.9.g Interchanges

The design of interchanges for the intersection of a freeway with a major street or highway, collector/distributor road, or other freeway is a complex problem. The location and spacing of intersections should follow the requirements presented in ***Section C.8 Access Control***, this chapter. The design of interchanges shall follow the general intersection requirements for deceleration, acceleration, merging maneuvers, turning roadways, and sight distance.

Interchanges, particularly along a given freeway, should be reasonably consistent in their design. A basic principle in the design should be to develop simple open interchanges that are easily traversed and understandable to the driver. Complex interchanges with a profusion of possible travel paths are confusing and hazardous to the motorist and are generally inefficient.

Intersections with minor streets or highways or collector/distributor roads may be accomplished by simple diamond interchanges. The intersection of exit and entrance ramps with the crossroad shall meet all intersection requirements.

The design of freeway exits should conform to the general configurations given in Table 3 – 22. Exits should be on the right and should be placed on horizontal curves. Where deceleration on an exit loop is required, the deceleration alignment should be designed so the driver receives adequate warning of the approaching increase in curvature. This is best accomplished by gradually increasing the curvature and the resulting centrifugal force. This increasing centrifugal force provides warning to the driver that he must slow down. A clear view of the exit loop should also be provided. The length of deceleration shall be no less than the values shown in Table 3 – 22.

Entrances to freeways should be designed in accordance with the general configurations shown below Table 3 – 21. Special care should be taken to ensure vehicles entering from loops are not directed across through travel lanes. The entering roadway should be brought parallel (or nearly so) to the through lanes before entry is permitted. Where acceleration is required, the distances shown in Table 3 – 21 shall, as a minimum, be provided. Exits and entrances to all high-speed facilities (design speed greater than 50 mph), should, where feasible, be designed in accordance with Tables 3 – 22 and 3 – 21. The lengths obtained from Tables 3 – 22 and 3 – 21 should be adjusted for grade by using the ratios in Table 3 – 20.

The selection of the type and exact design details of a particular interchange requires considerable study and thought. The guidelines and design details given in ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***, should generally be considered as minimum criteria.

### C.9.h Clear Zone

The provisions of ample clear zone or proper redirection of energy absorbing devices is particularly important at intersections. Every effort should be made to open up the area around the intersection to provide adequate clear zone for vehicles that have left the traveled way. Drivers frequently leave the proper travel path due to unsuccessful turning maneuvers or due to the necessity for emergency avoidance maneuvers. Vehicles also leave the roadway after intersection collisions and roadside objects should be removed to reduce the probability of second impacts. The roadside areas at all intersections and interchanges should be contoured to provide shallow slopes and gentle changes in grade.

The roadside clear zone of intersecting roadways should be carried throughout intersections with no discontinuities or interruptions. Poles and support structures for lights, signs, and signals should not be placed in medians or within the roadside clear zone.

The design of guardrails or other barriers should receive particular attention at intersections. Impact attenuators should be used in all gore and other areas where structures cannot be removed.

Particular attention should be given to the protection of pedestrians in intersection areas - ***Chapter 8 – Pedestrian Facilities***. Further criteria and requirements for clear zone and protection devices at intersections are given in ***Chapter 4 – Roadside Design***.

## C.10 Other Design Factors

### C.10.a Pedestrian Facilities

The layout and design of the street and highway network should include provisions for pedestrian traffic in urban areas. All pedestrian crossings and pathways within the road right of way should be considered and designed as in integral part of any street or urban highway.

#### C.10.a.1 Policy and Objectives - New Facilities

The planning and design of new streets and highways shall include provisions for the safe, orderly movement of pedestrian traffic. Provisions for pedestrian traffic outside of the road right of way should be considered.

The overall objective is to provide a safe, secure, continuous, convenient, and comfortable trip continuity and access environment for pedestrian traffic.

#### C.10.a.2 Accessibility Requirements

Pedestrian facilities, such as walkways and sidewalks, shall be designed to accommodate physically disabled persons whose mobility is dependent on wheelchairs and other devices. In addition to the design criteria provided in this chapter, the ***2006 Americans with Disabilities Act Standards for Transportation Facilities*** as required by 49 C.F.R 37.41 or 37.43 and the ***2012 Florida Accessibility Code for Building Construction*** as required by 61G20-4.002 impose additional requirements for the design and construction of pedestrian facilities.

### C.10.a.3 Sidewalks

Sidewalks should provide a safe, comfortable space for pedestrians. The width of sidewalks is dependent upon the roadside environment, volume of pedestrians, and the presence of businesses, schools, parks, and other pedestrian attractors. The minimum width for sidewalks is covered in ***Chapter 8 – Pedestrian Facilities*** and ***Section C.7.d*** of this chapter. To ensure compliance with federal and state accessibility requirements:

- Sidewalks less than 60 inches wide must have passing spaces of at least 60 inches by 60 inches, at intervals not to exceed 200 feet.
- The minimum clear width may be reduced to 32 inches for a short distance. This distance must be less than 24 inches long, and separated by 5-foot long sections with 48 inches of clear width.
- Sidewalks not constrained within the roadway right of way with slopes greater than 1:20 are considered ramps and must be designed as such.

Sidewalks 5 feet wide or wider will provide for two adults to walk comfortably side by side.

### C.10.a.4 Curb Ramps

In areas with sidewalks, curb ramps must be incorporated at locations where crosswalks adjoin the sidewalks. The basic curb ramp type and design application depends on the geometric characteristics of the intersection or other crossing location.

Typical curb ramp width shall be a minimum of 4 feet with 1:10 curb transitions on each side when pedestrians must walk across the ramp. Ramp slopes shall not exceed 1:10 and shall have a firm, stable, slip resistant surface texture. Ramp widths equal to crosswalk widths are encouraged.

Curb ramps at marked crossings shall be wholly contained within the crosswalk markings excluding any flared sides.

If diagonal ramps must be used, any returned curbs or other well-defined edges shall be parallel to the pedestrian flow. The bottom of diagonal curb ramps shall have 48-inch minimum clear space within the crosswalk. Curb ramps whose sides have returned curbs provide useful directional cues where they are aligned with the pedestrian street crossing and are protected from cross travel by landscaping or street, street furniture, or railings.

It is important for persons using the sidewalk that the location of the ramps be as uniform as possible. Detectable warnings are required at all curb ramps and flush transitions where sidewalks or shared use paths meet a roadway.

The Department's ***Design Standards, Index 304***, provides additional information on the design of accessible sidewalks and shared use paths. Designers should keep in mind there are many variables involved, possibly requiring each street intersection to have a unique design.

Two ramps per corner are preferred to minimize the problems with entry angle and to decrease the delay to pedestrians entering and exiting the roadway.

#### C.10.a.5 Additional Considerations

For additional information on pedestrian facilities design, including physical separation from the roadway, over- and underpasses, pedestrian crossings, traffic control, sight distance and lighting, refer to ***Chapter 8 – Pedestrian Facilities***.

### C.10.b Bicycle Facilities

Provisions for bicycle traffic should be incorporated into the street or highway design. All new roadways and major corridor improvements, except limited access highways, should be designed and constructed under the assumption they will be used by bicyclists. Roadway conditions should be favorable for bicycling. This includes appropriate drainage grates, pavement markings, and railroad crossings, smooth pavements, and signals responsive to bicycles. In addition, facilities such as bicycle lanes, shared use paths, and paved shoulders, should be included to the fullest extent feasible. All flush shoulder arterial and collector roadway sections should be given consideration for the construction of 4-foot or 5-foot paved shoulders. In addition, all curb and gutter arterial and collector sections should be given consideration for bicycle lanes.

For additional information on bicycle facilities design and the design of shared use paths, refer to ***Chapter 9 – Bicycle Facilities***.

### C.10.c Bridge Design Loadings

The minimum design loading for all new and reconstructed bridges shall be in accordance with ***Chapter 17 – Bridges and Other Structures***.

### C.10.d Dead End Streets and Cul-de-Sacs

The end of a dead end street should permit travel return with a turn around area, considering backing movements, which will accommodate single truck or transit vehicles without encroachment upon private property. Recommended treatment for dead end streets and cul-de-sacs is given in ***Figure 5 -1 Types of Cul-de-Sacs and Dead-End Streets*** of ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***.

### C.10.e Bus Benches and Transit Shelters

Bus benches should be set back at least 10 feet from the travel lane in curbed sections with a design speed of 45 mph or less, and outside the clear zone (Table 3 – 15) in flush shoulder sections.

Any bus bench or transit shelter adjacent to a sidewalk within the right of way of any street or highway shall be located so as to leave at least 48 inches of clearance for pedestrians and persons in wheelchairs. An additional one foot of clearance is required when any side of the sidewalk is adjacent to a curb or barrier. Such clearance shall be measured in a direction perpendicular to the centerline of the road. A separate bench pad or sidewalk flareout that provides a 30 inch wide by 48 inch deep wheelchair space adjacent to the bench shall be provided. Transit shelters should be set back, rather than eliminated during roadway widening.

Additional information on the design of transit facilities is found in ***Chapter 13 – Public Transit*** and ***Rule Chapter 14-20.003, Florida Administrative Code*** and ***Rule Chapter 14-20.0032, F.A.C***.

### C.10.f Traffic Calming

Often there are community concerns with controlling travel speeds impacting the safety of a street or highway such as in areas of concentrated pedestrian activities, those with narrow right of way, areas with numerous access points, on street parking, and other similar concerns. Local authorities may elect to use traffic calming design features that could include, but not be limited to, the installation of speed humps, speed tables, chicanes, or other pavement undulations. Roundabouts are also another method of dealing with this issue at intersections. For additional details and traffic calming treatments, refer to ***Chapter 15 – Traffic Calming***.

## C.11 Reconstruction

### C.11.a Introduction

The reconstruction (improvement or upgrading) of existing facilities may generate equal or greater safety benefits than similar expenditures for the construction of new streets and highways. Modifications to increase capacity should be evaluated for the potential effect on the highway safety characteristics. The long-range objectives should be to bring the existing network into compliance with current standards.

### C.11.b Evaluation of Streets and Highways

The evaluation of the safety characteristics of streets and highways should be directed towards the identification of undesirable features on the existing system. Particular effort should be exerted to identify the location and nature of features with a high crash potential. Methods for identifying and evaluating hazards include the following:

- Identification of any geometric design feature not in compliance with minimum or desirable standards. This could be accomplished through a systematic survey and evaluation of existing facilities.
- Review of conflict points along a corridor.
- Information from maintenance or other personnel.
- Review of crash reports and traffic counts to identify locations with a large number of crashes or a high crash rate.
- Review for expected pedestrian and bicycle needs.

### C.11.c Priorities

A large percentage of street and highway reconstruction and improvements is directed toward increasing efficiency and capacity. The program of reconstruction should be based, to a large extent, upon priorities for the improvement of safety characteristics.

The priorities for safety improvements should be based on the objective of obtaining the maximum reduction in crash potential for a given expenditure of funds. Elimination of conditions that may result in serious or fatal crashes should receive the highest priority in the schedule for reconstruction.

Specific high priority problem areas that should be corrected by reconstruction include the following:

- Obstructions to sight distance which can be economically corrected. The removal of buildings, parked vehicles, vegetation, large poles or groups of poles that significantly reduce the field of vision, and signs to improve sight distance on curves and particularly at intersections, can be of immense benefit in reducing crashes. The purchase of required line of sight easements is often a wise expenditure of highway funds. The establishment of sight distance setback lines is encouraged.
- Roadside and median hazards which can often be removed or relocated farther from the traveled way. Where removal is not feasible, objects should be shielded by redirection or energy absorbing devices. The reduction of the roadside hazard problem generally provides a good return on the safety dollar. Details and priorities for roadside hazard reduction, which are presented in ***Chapter 4 – Roadside Design***, should be incorporated into the overall priorities of the reconstruction program.
- Poor pavement surfaces which have become hazardous should be maintained or reconstructed in accordance with the design criteria set forth in ***Chapter 5 – Pavement Design and Construction***, and ***Chapter 10 – Maintenance and Resurfacing***.
- Specific design features which could be applied during reconstruction to enhance the operations and safety characteristics of a roadway include the following:
  - Addition of lighting.
  - Frontage roads may be utilized to improve the efficiency and safety of streets and highways with poor control of access.
  - Widening of pavements and shoulders. This is often an economically feasible method of increasing capacity and reducing traffic hazards. Provision of median barriers (***Chapter 4 – Roadside Design***) can also produce significant safety benefits.
  - The removal, streamlining, or modification of drainage structures.
  - Alignment modifications are usually extensive and require extensive reconstruction of the roadway. Removal of isolated

sharp curves is a reasonable and logical step in alignment modification. If major realignment is to be undertaken, every effort should be made to bring the entire facility into compliance with the requirements for new construction.

- The use of traffic control devices. This is generally an inexpensive method of alleviating certain highway defects.
- Median opening modifications.
- Addition of median, channelized islands, and mid-block pedestrian crossings.
- Auxiliary lanes.
- Existing bridges that fail to meet current design standards which are available to bicycle traffic, should be retrofitted on an interim basis as follows: As a general practice, bridges 125 feet in length or longer, bridges with unusual sight problem, steep gradients (which require the cyclist longer time to clear the span) or other unusual conditions should display the standard W11-1 caution sign with an added sign "On Bridge" at either end of the structure. Special care should be given to the right most portion of the roadway, where bicyclists are expected to travel, assuring smoothness, pavement uniformity, and freedom from longitudinal joints, and to ensure cleanliness. Failure to do so forces bicyclists farther into the center portion of the bridge, reducing traffic flow and safety.
- Addition of bicycle facilities.
- Addition of transit facilities, sidewalks, crosswalks, and other pedestrian features.

## C.12 Design Exceptions

See ***Chapter 14 – Design Exceptions*** for the process to use when the standard criteria found in this Manual cannot be met.

## C.13 Very Low-Volume Local Roads (ADT ≤ 400)

Where criteria is not specifically provided in this section, the design guidelines presented in Chapter 4 of the ***AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400), 1st Edition (2001)*** may be used in lieu of the policies in Chapter 5 of ***A Policy on Geometric Design of Highways and Streets (AASHTO, 2011)***. See Table 3 – 10 for lane widths for very low volume roads.

### C.13.a Bridge Width

Bridges are considered functionally obsolete when the combination of ADT and bridge width is used in the National Bridge Inventory Item 68 for Deck Geometry to give a rating of 3 or less. To accommodate future traffic and prevent new bridges from being classified as functionally obsolete, the minimum roadway width for new two lane bridges on very low-volume roads with 20 year ADT between 100 and 400 vehicles/day shall be a minimum of 22 feet. If the entire roadway width (traveled way plus shoulders) is paved to a width greater than 22 feet, the bridge width should be equal to the total roadway width. If significant ADT increases are projected beyond twenty years, a bridge width of 28 feet should be considered. One-lane bridges may be provided on single-lane roads and on two-lane roads with ADT less than 100 vehicles/day where a one-lane bridge can operate effectively. The roadway width of a one-lane bridge shall be 15 ft. One-lane bridges should have pull-offs visible from opposite ends of the bridge where drivers can wait for traffic on the bridge to clear.

### C.13.b Roadside Design

Bridge traffic barriers on very low-volume roads must have been successfully crash tested to a Test Level 2 (minimum) in accordance with ***NCHRP Report 350*** or ***Manual for Assessing Safety Hardware (MASH)***.

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# CHAPTER 4

# ROADSIDE DESIGN

# CHAPTER 4

# ROADSIDE DESIGN

## A INTRODUCTION

This chapter presents guidelines and standards for roadside designs intended to reduce the likelihood and/or consequences of roadside crashes. Construction and maintenance of safe medians and roadsides are of vital importance in the development of safe streets and highways.

Many of the standards presented in ***Chapter 3 - Geometric Design*** are predicated to a large extent upon reducing the probability of vehicles leaving the proper travel path. Other standards in that chapter are directed toward a reduction in the likelihood and/or consequences of crashes by vehicles leaving the roadway. These standards contain requirements for the design of shoulders, medians, and roadsides including requirements for the use of longitudinal barriers. Design of the roadside should be considered and conducted as an integral part of the total highway design.

Due to the variety of causative factors, the designer should consider a vehicle leaving the traveled way at any location. Design of the roadside should be based upon reducing the consequences to errant vehicles and their occupants.

## B POLICY

The roadside, which includes the median, shall be considered as the total environment adjacent to the roadway. The design of the roadside shall be considered as an integral part of the total highway design.

## C OBJECTIVES

General objectives to be followed in roadside design are to provide an environment that will reduce the likelihood and/or consequences of crashes by vehicles that have left the traveled way. The achievement of this general objective will be aided by the following:

- Roadside areas adequate to allow reasonable space and time for a driver to regain or retain control of the vehicle and stop or return to the traveled way safely.
- Shoulders, medians, and roadsides that may be traversed safely without vehicle vaulting or overturning.
- Location of roadside fixed objects and hazards as far from the travel lane as is economically feasible.
- Roadsides that accommodate necessary maintenance vehicles, emergency maneuvers and emergency parking.
- Protection of pedestrians, workers, or other persons subjected to the hazard of errant vehicles.
- Adequate protective devices (where hazards are unavoidable) compatible with vehicle speeds and other design variables.

# D ROADSIDE DESIGN

The basic requirements and standards for the design of shoulders, medians, and roadsides are given in ***Chapter 3 – Geometric Design***. This includes specific requirements regarding widths, slopes, and changes in grade. General requirements for drainage facilities, utilities, transit, and pedestrian facilities are also included.

This chapter contains general guidelines for particular situations encountered in roadside design due to the variety and complexity of possible situations encountered. The designer should utilize the following as basic guidelines to develop a safe roadside design.

Prior to any other consideration, the designer should attempt to:

1. Eliminate the hazard;
    a. Remove the hazard,
    b. Relocate the hazard outside of the clear zone,
    c. Make the hazard traversable or crashworthy.
2. Shield the hazard with a longitudinal barrier or crash cushion.
3. Leave the hazard unshielded. This treatment is taken only when the barrier or crash cushion is more hazardous than the hazard.

The AASHTO Roadside Safety Analysis Program (RSAP) is the recommended tool for evaluating the cost effectiveness of shielding roadside hazards.

## D.1 Geometric Changes

### D.1.a Horizontal Curves

On horizontal curves, consideration should be given to increasing the clear zone above the minimum requirements due to the increased likelihood of vehicles leaving the traveled way. Increasing clear zone widths and decreasing roadside slopes on curves is also important since a vehicle will probably leave the traveled way at a steeper exit angle. Increasing clear zone widths on curves is also beneficial in improving the available sight distance. Proper signage should be part of every roadside design. For proper signage to inform drivers of approaching curves, refer to the ***MUTCD.***

#### D.1.b Vertical Curves

As a vehicle comes over the crest of a vertical curve, the driver may suddenly be presented with a situation requiring an emergency maneuver. The provision of adequate clear zones is particularly important where available stopping sight distance may not be adequate or where driver expectancy may be violated. High traffic volumes (i.e., urban areas) may result in rapidly forming traffic queues, thus tending to cause rear-end collisions. Vertical curves with inadequate stopping sight distance may be mitigated with appropriate advanced signage and other warning devices, or can be reconstructed.

#### D.1.c Changes in Cross Section

The provision of adequate clear zone is very important at exits, entrances, lane drops, or other changes in the roadway cross section. The exterior boundaries of the clear zone should extend well beyond any reductions in roadway width and then gradually reduce to provide design width for the new roadway cross section.

#### D.1.d Decision or Conflict Points

Adequate clear zones should be provided at any point of traffic merging or conflicts, and at locations where the driver is confronted with making a decision regarding vehicle maneuvers.

### D.2 Fills

Many roadways, for drainage purposes, are elevated somewhat above the surrounding terrain. Where feasible, the side slopes should not exceed a ratio of 1:4. On flatter slopes (1:6 or greater), care should be exercised to eliminate sharp changes in grade or other discontinuities.

If the side slope is steeper than 1:3, longitudinal barriers should be considered.

## D.3 Cuts

A primary objective of roadside design in cut sections is to prevent conditions tending to cause rollovers or serious collisions with the cut slopes. When the material (soils) in the cut is smooth and stable, the use of an increasing backslope is a reasonable solution. The technique is also acceptable in stable rock cuts, provided that smooth fill material is utilized to affect the backslope.

The use of a rigid barrier incorporated into the cut slope is also satisfactory for rock slopes. Where the material in the cut is irregular or unstable, a longitudinal barrier offset from the cut face should be utilized.

## D.4 Roadside Canals

Roadside canals or other bodies of water close to the roadway should be eliminated wherever feasible. A canal is defined as an open ditch parallel to the roadway for a minimum distance of 1000 ft. and with a seasonal water depth in excess of 3 ft. for extended periods of time (24 hours or more).

Where roadside bodies of water (with seasonal water depth in excess of 3 feet for 24 hours or longer) lie within the roadside clear zone, they shall be shielded using guardrail or another longitudinal barrier.

For rural and urban flush shoulder highways, the distance from the outside edge of the through travel lane to the top of the canal side slope nearest the road will be no less than 60 ft. for highways with design speeds of 50 mph or greater. For highways with design speeds less than 50 mph this minimum distance shall not be less than 50 ft. for rural and urban flush shoulder highways or 40 ft. for urban curb or curb and gutter highways. When new canal or roadway alignment is required, distances greater than those above should be provided, if possible, to accommodate possible future improvements to the roadway (widening, etc.). If the minimum standards for canal hazards cannot be met, then shielding should be considered.

The RSAP is the recommended tool for evaluating the cost effectiveness of shielding roadside hazards.

## D.5 Vegetation

The proper use of natural vegetation can provide valuable and economical assistance in developing aesthetic and traversable roadsides.

### D.5.a Stability

The use of grass or other easily maintained, low-growing vegetation may be used on medians and roadsides. This vegetation should be carefully maintained so vehicles can safely traverse those areas.

### D.5.b Drainage

Drainage swales may be protected from hazardous scouring (alteration of safe ditch contour) by the appropriate vegetation. Grass, vines, or other plants can be beneficial in stabilizing embankments to prevent erosion of material onto adjacent roadways. The appropriate use of grass or shrubbery can also aid in retarding runoff in the vicinity of the roadway, thus benefiting the overall drainage pattern.

### D.5.c Environmental and Aesthetic Considerations

The use of natural grass and shrubbery for borders along roadways provides an important environmental asset. This border serves as a preserved green belt that minimizes the adverse impact (dirt, noise, etc.) of a street or highway. The use of a wide, gently flowing grassed roadside of varying width is generally an aesthetically pleasing design.

### D.5.d Landscaping - Design Considerations

The Department's ***Design Standards (Index Numbers 544 - Landscape Installations, and 546 - Sight Distance at Intersections)***, contain information on landscaping that may be considered. ***Index 544*** provides landscape installation details. The Department also produces the "Florida Highway Landscaping Guide" which is an excellent landscaping information source.

***Standard Index 546*** provides information on landscaping in vicinities of conventional intersections. Additional information for roundabout landscape guidelines and related sight line requirements can be found in ***NCHRP 672 "Roundabouts: An Informational Guide***."

## D.6 Drainage

Proper drainage of the pavement, shoulders, median, and roadsides is important for maintaining a safe street or highway. Techniques utilized for providing drainage should result in safe vehicle operation on or off the roadway.

### D.6.a Inlets

Drainage inlets should not be placed in a bus bay, travel, or bike lane and should not be placed in a shoulder, except at the exterior edge, when drainage restrictions are severe. Drainage inlets within the median or roadside(s) shall be traversable. A small area around the inlet should be paved to improve drainage and to prevent localized erosion. Corner radii inlets should be avoided as they hinder pedestrians, create ponding, create maintenance problems, and complicate intersection design.

### D.6.b Ditches

Drainage ditches perpendicular to the roadway should not be used within the median or roadsides. All drainage ditches within the median or roadsides shall meet the requirements for slopes and changes in grade given in ***Chapter 3 – Geometric Design***.

### D.6.c Culverts

Where culverts are unavoidable at intersections, the entrance and exit should be flush with the adjacent ground or located beyond the clear zone. The slope and changes in grade at the structure should conform to minimum requirements for roadsides. Culvert terminations at median crossovers should be constructed in a similar fashion.

Where culverts are required perpendicular to the roadway, they should be extended to the roadsides as a minimum. Headwalls at the culvert terminations (within the clear zone) should not protrude above the ground surface in excess of 4 inches. Sloping entrances and exits generally flush with side slopes should be used wherever possible (even outside the clear zone). Proper ground contouring of the roadside approach can provide a relatively smooth surface that can be traversed with reasonable safety by an errant vehicle.

Cross drains and side drains within the clear zone should be equipped with mitered end sections. ***FDOT Standard Index Series 200*** provides additional information on the proper design and use of flared and mitered end sections.

## D.7 Curbs

The basic criteria for prohibiting or permitting the use of curbs are given in Chapter 3 - Geometric Design. Curbs serve any or all of the following purposes: drainage control, roadway edge delineation, right of way reduction, aesthetics, delineation of pedestrian walkways, reduction of maintenance operations, and assistance in orderly roadside development.

Curbs should not be used along freeways or other high-speed arterials, but if a curb is needed, it should not be located closer to the traveled way than the outer edge of the shoulder. In addition, sloping end treatments should be provided.

## D.8 Poles and Support Structures

The location and design of poles or support structures for signs, signals, lighting, or other purposes is an important aspect of safe roadside design. All poles and support structures should be located outside the required clear zone when practical unless their supports are of the frangible or breakaway type. Non-breakaway poles and sign support structures may be located behind a barrier that is present for another reason. For proper offset from rigid obstacles to barriers, see section "E" of this chapter.

The function of a breakaway support is to minimize the vehicle deceleration and the probability of injury to vehicle occupants. The design of the support should also be adequate to prevent portions of the structure from penetrating the vehicle interior.

Small signs should be designed to bend over flush with the ground upon impact. Larger signs should be designed with multiple posts with slip joints at the base and a weakened section and fuse plate intended to act as a hinge at the bottom of the sign.

Utility poles and structures not related to highway operations, should be located outside the clear zone and as close as practical to the edge of right of way, without aerial encroachment, and without violating National Electric Safety Code (NESC) clearances. New utility poles not placed at the edge of the right of way, and falling within the limits of the clear zone dimensions defined in ***Chapter 3 - Geometric Design***, Table 3 –15 Minimum Width of Clear Zone should be approved through the exception process prescribed in ***Chapter 14 – Design Exceptions***. Placement within sidewalk shall be such that a minimum unobstructed sidewalk width of 32" is provided.

In accordance with ***Section 337.403, Florida Statutes***, existing utility poles must be relocated when ***unreasonably*** interfering with the "convenient, safe, or continuous use, or the maintenance, improvement, extension, or expansion" of public roads. Utility poles adjacent to road improvement projects, but not directly interfering with construction, should be considered for relocation, to the extent they can be relocated, to achieve the clear zone requirements of Table 3-12. Utility poles that cannot be relocated and will remain within the clear zone, should be approved through the exception process prescribed in ***Chapter 14 – Design Exceptions***.

## D.9 Intersections

All poles or other structures not absolutely essential should not be located in the vicinity of the intersection. When joint use agreements can be arranged, the various governmental agencies, transit authorities, and utilities should consider the use of joint purpose single poles as a replacement for all poles or structures serving a single purpose. Light poles, traffic signal supports and boxes, transit stop signs, and all other street furniture should be moved back as far as is practical from the boundary of the roadsides.

Energy absorbing devices should be considered for protection of lighting and traffic signal supports located within the roadsides.

## D.10 Underpasses

The full median and roadside should be carried through underpasses without interruption. Where it is not feasible to eliminate the supports, guardrail or another longitudinal barrier should be used. The barrier may be a rigid barrier incorporated into the support columns or a guardrail set out from the supports. The barrier should be extended well beyond the supports.

## D.11 Bridges and Overpasses

The required lateral offset (***Chapter 3 – Geometric Design***) should be maintained on all bridges, overpasses, or other elevated roadways. The full roadway cross section, including shoulders, should be carried across without interruption. Bridge railings should be designed and constructed in compliance with the requirements for redirection barriers. Particular emphasis should be placed on the prevention of structural failure and vaulting of the railing by errant vehicles.

On all high speed roadways (design speed 50 mph or greater), the bridge railing or other barriers should be extended sufficiently (and properly terminated) to prevent vehicles from passing behind the barrier and entering the hazardous location. The transition between the bridge railing and the approach barrier should be smooth and continuous. Barrier curbs should not be placed in front of bridge railings or other barriers. Pedestrian facilities should be placed outside of the bridge railing or longitudinal barrier on all high speed roadways.

It is desirable that twin bridges for nominal width median divided highways be filled in the dividing area, carrying the median across the bridge without interruption. The gore area between diverging elevated roadways should be bridged over for a sufficient distance to allow for the placement of any energy absorbing devices. If twin bridges are used, the median layout should conform to ***Chapter 3 – Geometric Design***.

See ***Chapter 17 – Bridges and Other Structures*** for additional requirements for bridges and bridge railings.

## D.12 Mailboxes

Guidelines for the location of mailboxes, type of support and turnout construction, given in the Department's ***Design Standards, Index 532 - Mailboxes*** or ***AASHTO - "A Guide for Erecting Mailboxes on Highways"***, should be considered.

## D.13 Bus Shelters

Bus shelters should be moved back as far as practical from the roadside with pedestrian access to the bus stop boarding and alighting area at the roadside.

# E PROTECTIVE DEVICES

Protective devices for roadside design may be considered as highway safety features intended to reduce the severity of run-off-the-road crashes. In those situations where the minimum safety standards for median and roadside are not feasible, protective devices should be considered. Longitudnal barriers should not be used indiscriminately, for at least two reasons: they are expensive to install and maintain, and they are closer to the road than the obstacles they are shielding. They should be used when they are warranted by the reduction in crash severity.

Refer to the Department's ***Plans Preparation Manual, Chapter 4 Roadside Safety*** for additional information on roadside and median barriers and crash cushions.

## E.1 Redirection Devices

Redirection devices are longitudinal barriers, such as guardrails, median barriers, and bridge railings placed parallel to the roadway to contain and redirect errant vehicles.

### E.1.a Function

The primary function of a longitudinal barrier is to redirect an errant vehicle away from hazardous roadside obstacles. The barrier should be designed to produce a minimum of adverse impacts (lateral and longitudinal) to a vehicle.

### E.1.b Warranting Conditions

Warranting conditions for the use of longitudinal barriers are essentially those conditions in which the overall probability of injuries and fatalities would be reduced by the use of these redirection devices. ***AASHTO's Roadside Design Guide*** contains warrants related to roadside barrier selection and placement.

### E.1.c Location

Ideally, the barrier should be located to minimize the likelihood of being struck by an errant vehicle. The barrier should be located outside the normal shoulder width. The location and orientation of the barrier should also be selected to minimize the angle of impact and the resulting vehicle deceleration.

Barriers shall be offset from obstacles or other hazards a sufficient distance so the barrier may deflect without interference. The location of the barrier should be selected in close coordination with the design of its deflection characteristics.

### E.1.d Length

The length of a longitudinal barrier should be sufficient to prevent a vehicle, traveling in either direction, from passing behind the barrier and striking the hazard being shielded.

### E.1.e Vehicle Containment

Longitudinal barriers should have sufficient strength to prevent a vehicle from penetrating the barrier. Structural continuity and smoothness is also required to prevent rapid deceleration or penetration of the vehicle by any of the barrier components. The shape and height of the barrier should be adequate to deter overturning or vaulting of the vehicle. The surface in front of the barrier should be approximately perpendicular to the barrier and should be free from barrier curbs or other discontinuities.

### E.1.f Barrier Types

Longitudinal barriers may be generally classified as rigid or flexible. The recommended barriers in the following sections are intended as general guidelines only. As new types of barriers are developed and tested successfully, they may be incorporated into roadside design. They should, however, conform with the requirements previously established.

- Rigid Barrier - Rigid barriers are generally less effective in controlling lateral vehicle deceleration at locations subject to high-angle impacts. The use of this barrier is recommended for bridge railings and for use at retaining walls, rock cuts, or other rigid hazards where space limitations are constrained.

- Flexible Barrier - Barriers which yield somewhat on impact are often more useful in limiting the rate of vehicle deceleration. Special care should be exercised to ensure they are structurally adequate and they maintain a smooth continuous surface.

  This type of barrier can be expected to deflect 2 to 5 feet under impact. The post spacing may be increased when a stiffer rail is utilized. The weak post barrier and the cable barrier can be expected to deflect 8 to 12 feet or more and should be limited to locations with adequate clear space.

#### E.1.g Transitions

Changes in barrier types should be kept to a minimum. Transitions between two types of barriers should be smooth and continuous with no protruding components that could snag or penetrate a vehicle striking the barrier from either direction of travel. The transition from a flexible to a rigid barrier should be stiffened gradually to prevent "pocketing" of an errant vehicle.

#### E.1.h Terminations

Barrier terminations or interruptions should be kept to a minimum. The barrier termination should be designed to allow for a reasonably safe traversal by a vehicle traveling in either direction.

Roadside guardrails should be flared away from the roadway. The use of energy absorbing devices as the termination of the longitudinal barrier is an effective and acceptable procedure for both roadsides and medians.

### E.2 Energy Absorbing Devices

#### E.2.a Function

The primary function of an energy absorbing device or crash cushion is to reduce the severity of impacts with fixed objects. These are utilized at locations where impact with the roadside obstacle would produce a greater deceleration rate. The deceleration rate is controlled by providing a cushion which deforms and absorbs energy while bringing the vehicle gradually to a stop.

### E.2.b Warranting Conditions

Crash cushions are used for the protection of occupants of an errant vehicle which might strike obstacles within the median or roadside that would produce excessive vehicle deceleration.

Other locations or situations that should be considered for crash cushions include:

- Gore areas on elevated roadways
- Intersections
- Barrier terminations
- Bridge abutments and supports
- Retaining walls
- Any other roadside object subject to impact by an errant vehicle

### E.2.c Design Criteria

The primary design criteria are the limitation of vehicle deceleration which is a function of the vehicle speed and the total crash cushion deformation.

The crash cushion should be located as far from the roadway as is practicable to reduce the likelihood of impact. Special care should be exercised in the design to reduce the probability of a vehicle overturning or vaulting the crash cushion.

### E.2.d Design Details

The development and testing of crash cushions are both recent and rapid. The rapidly expanding technology in this field requires the most recent research and experience be utilized in selecting a particular type of crash cushion. ***AASHTOs Roadside Design Guide*** provides guidance for the selection of sacrificial, re-useable and low maintenance crash cushion types.

# F REFERENCES FOR INFORMATIONAL PURPOSES

The following is a list of publications that may be referenced for further guidance:

- ***AASHTO Roadside Design Guide***
  https://bookstore.transportation.org/

- ***NCHRP Report 672 – Roundabouts: An Informational Guide, Second Edition***
  http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf

- ***Section 401, Florida Statutes***
  http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0300-0399/0337/Sections/0337.401.html

- ***FDOT Drainage Manual, January 2017***
  *http://www.fdot.gov/roadway/Drainage/ManualsandHandbooks.shtm*

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# CHAPTER 5

# PAVEMENT DESIGN AND CONSTRUCTION



# FIGURES

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# CHAPTER 5

# PAVEMENT DESIGN AND CONSTRUCTION

## A INTRODUCTION

The function of the pavement or roadway surface is to provide a safe and efficient travel path for vehicles using the street or highway. The pavement should provide a good riding surface with a minimum amount of distraction to the driver. The pavement friction characteristics should be such that adequate longitudinal and lateral forces between the vehicle tires and the pavement can be developed to allow a margin of safety for required vehicle maneuvers. These characteristics should be provided at the highest reasonable level for the expected pavement surface, weather conditions, and the anticipated operational characteristics of the facility. Resurfacing of the existing pavement is discussed and included under ***Chapter 10 – Maintenance and Resurfacing*** of the manual.

In order for the pavement to perform its function properly, the following objectives shall be considered in the design and construction of the pavement:

- Provide sufficient pavement structure and the proper pavement material strength to prevent pavement distress prior to the end of the design period.
- Develop and maintain adequate skid resistance qualities to allow for safe execution of braking, cornering, accelerating, and other vehicle maneuvers.
- Provide drainage to promote quick drying and to reduce the likelihood of hydroplaning and splashing.
- Provide a Safety Edge treatment adjacent to the travel lane on roadways without curb or paved shoulders and with posted speed 45 mph or greater.

# B PAVEMENT DESIGN

## B.1 Pavement Type Selection

For new construction and major reconstruction projects, the designer should determine the type of pavement to be constructed utilizing formal analysis of existing and anticipated conditions. High volume roadways where a significant amount of truck traffic (>10%) exists may warrant consideration for special asphalt pavement designs and for rigid pavement designs. The Department has a documented procedure patterned after the 1993 AASHTO Guide for Design of Pavement Structures, Appendix B. This procedure may be found in Department's Pavement Type Selection Manual.

### B.1.a Unpaved Roadway Material Selection

The material chosen should be locally available when possible. Frequency of grading and replacement of material from loss due to erosion should be evaluated. A life cycle economic analysis should be performed to determine suitable material type. For example: Un-recycled asphalt pavements (Un-RAP) provide for a suitable all weather material and can be considered for unpaved roads.

The material chosen should exhibit low potential for losses due to wind, traffic and water erosion. EPA’s publication AP-42 contains methodology for estimating the dust generation potential for unpaved road surfaces. Proper gradation of the chosen material is critical for its success. Designers should consider flexible or rigid pavements where runoff from unpaved roads may impact surface waters.

Designers may consult with FHWA’s publications “***Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT < 400), 2001***” and “***Gravel Roads Maintenance and Design Manual, 2000***” for further guidance regarding material selection.

## B.2 Structural Design

The pavement shall be designed and constructed so the required surface texture is maintained and its structure retains an adequate level of serviceability for the design period. The strength of the pavement materials shall be sufficient to maintain the desired roadway cross section without the formation of ruts or other depressions which would impede drainage. Subgrade strength and subgrade drainage are major factors to be considered in pavement design.

The Department's pavement design manuals are recommended as a guide for both flexible and rigid pavement design. Other design procedures are available including the ***AASHTO Guide for Design of Pavement Structures, 1993***; and procedures which have been developed by the Portland Cement Association, the American Concrete Pavement Association, and the Asphalt Institute. The selection of the design procedure and the development of the design data must be managed by professional personnel competent to make these evaluations.

## B.3 Skid Resistance

Pavements shall be designed and constructed so as to maintain adequate skid resistance for as long a period as the available materials, technology, and economic restraints will permit, thus eliminating cost and hazardous maintenance operations.

The results of relevant experience and testing (i.e., tests conducted by the Department's Materials Office) should be used in the selection of aggregate and other materials, the pavement mix design, the method of placement, and the techniques used for finishing the pavement surface. The design mixes should be monitored by continuous field testing during construction. Changes to the design mix or construction procedures must be made by qualified pavement designers and laboratory personnel ONLY.

The use of transverse grooving in concrete pavements frequently improves the wet weather skid resistance and decreases the likelihood of hydroplaning. This technique should be considered for locations requiring frequent vehicle maneuvers (curves, intersections, etc.) or where heavy traffic volumes or high speeds will be encountered. The depth, width, and spacing of the grooves should be such that control of the vehicle is not hindered.

## B.4 Drainage

Adequate drainage of the roadway and shoulder surfaces should be provided. Factors involved in the general pavement drainage pattern include: pavement longitudinal and cross slopes, shoulder slopes and surface texture, curb placement, and the location and design of collection structures. The selection of pavement cross slopes should receive particular attention to achieve the proper balance between drainage requirements and vehicle operating requirements. The use of curbs or other drainage controls adjacent to the roadway surface should be avoided, particularly on high speed facilities. Specific requirements for cross slopes and curb placement are given in ***Chapter 3 – Geometric Design***.

### B.4.a Unpaved Roadway Drainage

Properly graded unpaved roadways require less maintenance and suffer less material loss. Designers should strive to provide adequate cross slope, shoulder and swale profiles wherever possible. Typical cross slopes should be 2% with 1.5% minimum. During maintenance grading, the operator should ensure that the shoulder does not become higher than the travel lane edge to prevent ponding of water on the roadway.

Designers may consult with FHWA's publications: ***Guidelines for Geometric Design of Very Low-Volume Roads (ADT < 400), 2001*** and "Gravel Roads Maintenance and Design Manual, 2000" for further guidance regarding proper profiles for unpaved roads.

## B.5 Shoulder Treatment

The primary function of the shoulder is to provide an alternate travel path for vehicles in an emergency situation. Shoulders should be capable of providing a safe path for vehicles traveling at roadway speed, and should be designed and constructed to provide a firm and uniform surface capable of supporting vehicles in distress. Particular attention shall be given to provide a smooth transition from pavement to shoulder.

Safety Edge is a technology that mitigates vertical drop offs. The Safety Edge provides a higher probability of a vehicle returning safely to the travel lane when it drifts off the pavement. The wedge shape eliminates tire scrubbing and improves vehicle stability as it crosses a drop-off. Details for the Safety Edge are included in Figures 5 – 1 Two Lane Road with Safety Edge and 5 – 2 Safety

Edge Detail (No Paved Shoulders).

**FIGURE 5 – 1 Two Lane Road with Safety Edge**

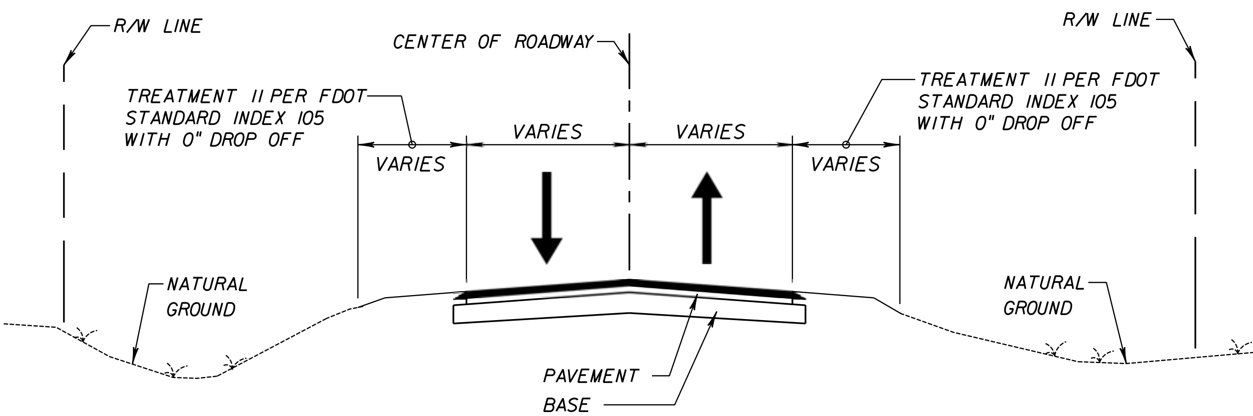
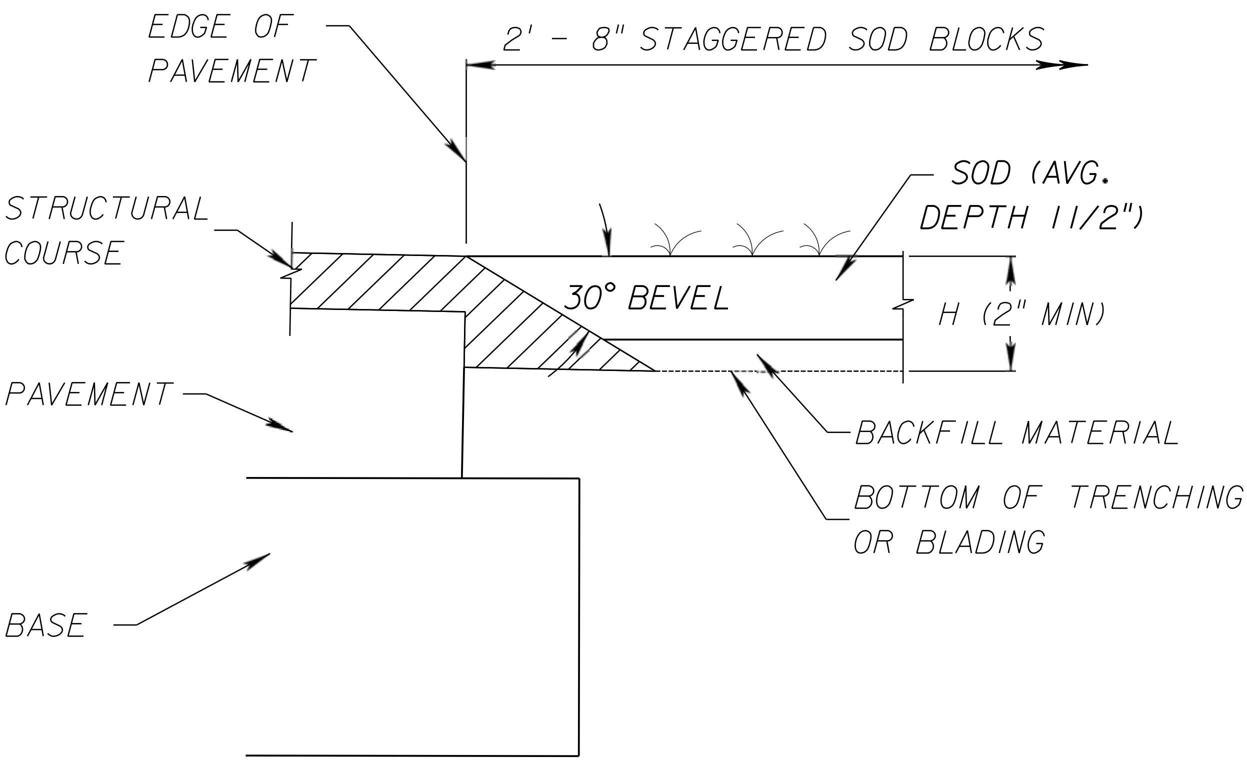


**FIGURE 5 – 2 Safety Edge Detail (No Paved Shoulders)**




FOR 2" ≤ H ≤ 5"

SINGLE LIFT
SAFETY EDGE DETAIL

Shoulder pavement may be provided to improve drainage of the roadway, to serve bicycles, pedestrians and transit users, and to minimize shoulder maintenance.

# C PAVEMENT CONSTRUCTION

A regular program of inspection and evaluation should be conducted to ensure the pavement criteria are satisfied during the construction process. Any regular inspection program should include the following:

- The use of standard test procedures, such as AASHTO and the American Society for Testing and Materials (ASTM).
- The use of qualified personnel to perform testing and inspection.
- The use of an independent assurance procedure to validate the program.

After construction, the pavement surface shall be inspected to determine the required surface texture was achieved and the surface has the specified slopes. Spot checking skid resistance by approved methods should be considered. Periodic reinspection should be undertaken in conformance with the guidelines described in ***Chapter 10 – Maintenance and Resurfacing***.

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# CHAPTER 6

# LIGHTING

# TABLES

# CHAPTER 6

# LIGHTING

## A INTRODUCTION

The major reason for lighting streets and highways is to improve safety for vehicular and pedestrian traffic. Improvements in sight distance and reduction of confusion and distraction for night time driving can reduce the hazard potential on streets and highways. There is evidence indicating that highway lighting will produce an increase in highway capacity as well as improve the economic, safety, and aesthetic characteristics of highways.

Experience and technical improvements have resulted in improved design of lighting for streets and highways. Photometric data provide a basis for calculation of the illumination at any point for various combinations of selected luminaire types, heights, and locations. Lighting engineers can develop lighting systems that will comply with the requirements for level and uniformity of illumination; however, some uncertainties preclude the adoption of rigid design standards. Among these uncertainties is the lack of understanding in the area of driver response and behavior under various lighting conditions. The design of lighting for new streets and highways, as well as improvements on existing facilities, should be accompanied by careful consideration of the variables involved in driver behavior and problems peculiar to particular locations.

Rights of way with pedestrian sidewalks and/or bikeways adjacent to the roadway should first address lighting requirements for the roadway to assure it is continuously illuminated. Additional lighting for a sidewalk or shared use path maybe necessary if it is substantially set back from the roadway, at the discretion of the responsible/maintaining agency. Pedestrian sidewalks and/or bikeways should not be illuminated in lieu of lighting the adjacent roadway in order to avoid glare or potential lighting distractions to drivers.

## B OBJECTIVES

The objective for providing lighting is to improve the safety of roadways, sidewalks, and shared use paths and visibility of signs for road users (drivers, pedestrians, and bicyclists). The achievement of this objective will be aided by meeting these specific goals:

- Provide an improved view of the general highway geometry and the adjacent environment.
- Increase the sight distance to improve response to hazards and decision points.
- Eliminate "blind" spots unique to travel at night or in low light conditions.
- Provide a clearer view of the general situation during police, emergency, maintenance, and construction operations.
- Provide assistance in roadway, sidewalk or path delineation, particularly in the presence of confusing background lighting (i.e., surrounding street and other area lighting confuses the driver on an unlighted street or highway).
- Minimize glare that is discomforting or disabling.
- Reduce abrupt changes in light intensity.
- Avoid the introduction of roadside hazards resulting from improper placement of light poles, pull boxes, etc. (as covered under ***Chapter 3 – Geometric Design*** and ***Chapter 4 – Roadside Design***).

# C WARRANTING CONDITIONS

Although precise warrants for the provision of roadway lighting are difficult to determine, criteria for lighting is established and should be followed for construction and for improvement of existing facilities. The following locations should be considered as a basis for warranting roadway lighting:

## C.1 Criteria Based Upon Crash History

- Locations where pedestrians assemble to board or depart from transit services.
- Locations that, by a crash investigation program, have been shown to be hazardous due to inadequate lighting.
- Locations where the night/day ratio of serious crashes is higher than the average of similar locations.
- Specific locations that have a significant number of night time crashes and where a large percentage of these night time crashes result in injuries or fatalities.

## C.2 Criteria Based Upon Analysis and Investigation

- Locations requiring a rapid sequence of decisions by the road user.
- Locations where night sight distance problems exist, with particular consideration to headlight limitations (i.e., where vertical and horizontal curvature adversely affect illumination by headlamps).
- Locations having discomforting or disabling glare.
- Locations where background lighting exists, particularly if this could be distracting or confusing to the road user.
- Locations where improved delineation of the highway alignment is needed.

## C.3 General Criteria

- Roundabouts.
- Urban collector streets, particularly with high speed, high volumes, or frequent turning movements.
- Urban streets of any category experiencing high night time volumes or speeds or that have frequent signalization or turning movements.
- Areas frequently congested with vehicular and/or pedestrian traffic.
- Pedestrian and bicyclist crossings (intersections or mid-block locations), and areas such as entertainment districts, sporting arenas, shopping centers, beach access, parks, and other locations that generate higher volumes of pedestrian activity.
- Schools, places of assembly, transit stops, or other pedestrian or bicyclist generators.
- High density land use areas.
- Central business districts.
- Junctions of major highways in rural areas.
- Rest areas/picnic shelters/trail heads/recreational facilities.

## D TYPES OF ILLUMINATION

Examples of common types of lighting are identified and discussed below. Other types of lighting may be desired and currently in use for specific applications.

- High Pressure Sodium (HPS) Lamps – is the most commonly used light source for street lighting. Light produced by HPS lamps has a correlated color temperature (CCT) around 2100°K which is a warm yellow color. The average rated life for an HPS lamp is from 24,000 to 30,000 hours. HPS lamps have a very high initial luminous efficacy of over 100 lumens per watt.

- Metal Halide (MH) Lamps – is commonly used for overhead lighting of commercial parking lots, sports facilities, retail stores and street lighting. Light produced by MH lamps has a CCT of 3800°K to 4000°K which is a white color. The average rated life of a MH lamp can vary from 9,000 to 20,000 hours. MH lamps have a high initial luminous efficacy of around 75 - 100 lumens per watt.

- Light Emitting Diode (LED) – although LED was developed in the early 1960s, it has only recently entered the roadway lighting market. Light produced by LED lamps have a CCT of 4000°K to 6000°K which is a white to bluish color. The average rated life for LED can vary from 50,000 to 100,000 hours. The wide variation in rated life for LED's is due to the limited lumen output of a single LED. To provide sufficient lumens for roadway lighting requires that fixtures have a large number of LED's. To maximize the lumen output of each LED, fixture manufactures may use a variety of techniques to increase the lumen output such as increasing the CCT and increasing the drive current. Increasing the CCT from 3500°K to 4500°K results in an 8% increase in lumen level, however above 4500°K the rate of increase doubles. Increasing the CCT also improves the efficacy of LED's. LED's are most efficient at drive currents of 350mA or 525mA, however they can be driven as high as 2100mA. A 25% increase in lumen level can be achieved by increasing the drive current from 525mA to 700mA. The increase in lumen level drops slightly to 21% for each 175mA increase from 700mA to 1400mA. Above 1400mA, the increase in lumen level drops to 6% for each 175mA. Increasing the drive current to LED's has two serious consequences, it substantially reduces the average rated life and the efficiency of the LED. To provide sufficient lumen levels for roadway applications, most LED fixtures have an initial luminous efficacy of around 75 lumens per watt.

## E LEVEL OF ILLUMINATION

It is recommended that the level of illumination for streets and highways not be less than:

- Levels consistent with need and resources.
- Guidelines found in Table 6 – 1 Level of Illumination for Streets and Highways on the following page.
- Lighting of mid-block pedestrian crossings at 2.0 foot candles of average maintained *vertical* illumination should be provided when night time pedestrian activity is expected.

When adding supplemental lighting for pedestrian activity, ensure lighting is compatible with any existing lighting in the corridor and minimizes glare. Illuminance in roadway lighting is a measure of the light at the pavement surface. Luminance in roadway lighting is a measure of the reflected light from the pavement surface that is visible to the motorist's eye. See Table 6 – 1 for ranges of illumination.

These levels are for the purpose of highway safety and do not apply to lighting levels required for crime reduction. Further information may be found in the ***AASHTO - Roadway Lighting Design Guide (2005)***.

## TABLE 6 – 1 Level of Illumination for Streets and Highways

| Roadway and Walkway Classification | Off-Roadway Light Sources | Illuminance Method | | | | | Luminance Method | | | Additional Values (both Methods) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Average Maintained Illuminance (Horizontal) | | | | Illuminance Uniformity Ratio | Average Maintained Luminance | | | Veiling Luminance Ratio |
| | | R1 | R2 | R3 | R4 | | Lavg | Uniformity | | |
| | General Land Use | (foot -candles) (min) | (foot-candles) (min) | (foot-candles) (min) | (foot-candles) (min) | avg/min (max) (6) | cd/m2 (min) | Lavg/Lmin (max) | Lmax/Lmin (max) | Lv(max)/Lavg (max)$^{(3)}$ |
| Principal Arterials (partial or no control of access) | Commercial | 1.1 | 1.6 | 1.6 | 1.4 | 3:1 | 1.2 | 3:1 | 5:1 | 0.3:1 |
| | Intermediate | 0.8 | 1.2 | 1.2 | 1.0 | 3:1 | 0.9 | 3:1 | 5:1 | 0.3:1 |
| | Residential | 0.6 | 0.8 | 0.8 | 0.8 | 3:1 | 0.6 | 3.5:1 | 6:1 | 0.3:1 |
| Minor Arterials | Commercial | 0.9 | 1.4 | 1.4 | 1.0 | 4:1 | 1.2 | 3:1 | 5:1 | 0.3:1 |
| | Intermediate | 0.8 | 1.0 | 1.0 | 0.9 | 4:1 | 0.9 | 3:1 | 5:1 | 0.3:1 |
| | Residential | 0.5 | 0.7 | 0.7 | 0.7 | 4:1 | 0.6 | 3.5:1 | 6:1 | 0.3:1 |
| Collectors | Commercial | 0.8 | 1.1 | 1.1 | 0.9 | 4:1 | 0.8 | 3:1 | 5:1 | 0.4:1 |
| | Intermediate | 0.6 | 0.8 | 0.8 | 0.8 | 4:1 | 0.6 | 3.5:1 | 6:1 | 0.4:1 |
| | Residential | 0.4 | 0.6 | 0.6 | 0.5 | 4:1 | 0.4 | 4:1 | 8:1 | 0.4:1 |
| Local | Commercial | 0.6 | 0.8 | 0.8 | 0.8 | 6:1 | 0.6 | 6:1 | 10:1 | 0.4:1 |
| | Intermediate | 0.5 | 0.7 | 0.7 | 0.6 | 6:1 | 0.5 | 6:1 | 10:1 | 0.4:1 |
| | Residential | 0.3 | 0.4 | 0.4 | 0.4 | 6;1 | 0.3 | 6:1 | 10:1 | 0.4:1 |
| Alleys | Commercial | 0.4 | 0.6 | 0.6 | 0.5 | 6:1 | 0.4 | 6:1 | 10:1 | 0.4:1 |
| | Intermediate | 0.3 | 0.4 | 0.4 | 0.4 | 6:1 | 0.3 | 6:1 | 10:1 | 0.4:1 |
| | Residential | 0.2 | 0.3 | 0.3 | 0.3 | 6:1 | 0.2 | 6:1 | 10:1 | 0.4:1 |

Continued on next page

**TABLE 6 – 1**
**Level of Illumination for Streets and Highways**
(Continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sidewalks | Commercial | 0.9 | 1.3 | 1.3 | 1.2 | 3:1 | Use illuminance requirements |
| | Intermediate | 0.6 | 0.8 | 0.8 | 0.8 | 4:1 | |
| | Residential | 0.3 | 0.4 | 0.4 | 0.4 | 6:1 | |
| Pedestrian Ways and Bicycle Ways(2) | All | 1.4 | 2.0 | 2.0 | 1.8 | 3.1 | |

Notes

1. Meet either the Illuminance design method requirements or the Luminance design method requirements and meet veiling luminance requirements for both illuminance and Luminance design methods.
2. Assumes a separate facility. For Pedestrian Ways and Bicycle Ways adjacent to roadway, use roadway design values. Use R3 requirements for walkway/bikeway surface materials other than the pavement types shown.
3. Lv (max) refers to the maximum point along the pavement, not the maximum in lamp life. The Maintenance factor applies to both the Lv term and the Lavg term.
4. There may be situations when a higher level of illuminance is justified. The higher values for freeways may be justified when deemed advantageous by the agency to mitigate off-roadway sources.
5. Physical roadway conditions may require adjustment of spacing determined from the base levels of illuminance indicated above.
6. Higher uniformity ratios are acceptable for elevated ramps near high-mast poles.
7. See AASHTO publication entitled, “A Policy on Geometric Design of Highways and Streets” for roadway and walkway classifications.
8. R1, R2, R3 and R4 are Road Surface Classifications, defined in the AASHTO Roadway Lighting Design Guide and further described in Table 6.2.

A system of pavement reflectance values divides the pavement characteristics into four categories: R1, R2, R3 and R4. These categories are based upon the ***American National Standard Practice for Roadway Lighting*** and have been adopted by ***AASHTO*** in their ***Roadway Lighting Design Guide***. They are described in Table 6- 2 Road Surface Classifications.

**Table 6 – 2**
**Road Surface Classifications**

| Class | $Q_0$* | Description | Mode of Reflectance |
|---|---|---|---|
| R1 | 0.10 | Portland cement concrete road surface. Asphalt road surface with a minimum of 12% of the aggregates composed of artificial brightener or aggregates. | Mostly diffuse |
| R2 | 0.07 | Asphalt road surface with an aggregate composed of minimum 60% gravel (size greater than 0.4 in.).<br>Asphalt road surface with 10 to 15% artificial brightener in aggregate mix. (Not normally used in North America). | Mixed (diffuse and specular) |
| R3 | 0.07 | Asphalt road surface (regular and carpet seal) with dark aggregates (e.g., trap rock, blast furnace slag); rough texture after some months of use typical highways). | Slightly specular. |
| R4 | 0.08 | Asphalt road surface with very smooth texture. | Mostly specular. |

* $Q_0$ = representative mean luminance coefficient.

## F UNIFORMITY OF ILLUMINATION

In order to avoid vision problems due to varying illumination, it is important to maintain illumination uniformity over the roadway. It is recommended the ratio of the average to the minimum initial illumination on the roadway be between 3:1 to 4:1.

A maximum to minimum uniformity ratio of 10:1 should not be exceeded. It is important to allow time for the driver's eye to adjust to lower light levels. The first light poles should be located on the side of the incoming traffic approaching the illuminated area. The eye can adjust to increased or increasing light level more quickly. In transition from a lighted to an unlighted portion of the highways, the level should be gradually reduced from the level maintained on the lighted section. This may be accomplished by having the last light pole occur on the opposite roadway. The roadway section following lighting termination should be free of hazards or decision points. Lighting should not be terminated before changes in background lighting or roadway geometry, or at the location of traffic control devices.

It is also important to ensure color consistency when lighting a highway/pedestrian corridor. Mixing of different types of lighting may reduce the lighting uniformity. As we transition to LED, it is acceptable to have mixed lighting segments along the same corridor.

The use of spot lighting at unlit intersections with a history of nighttime crashes is an option.

Close coordination between the Engineer of Record and the responsible local governmental agency is essential.

# G UNDERPASSES and OVERPASSES

One of the criteria to be followed to determine requirements for underpass lighting is the relative level between illumination on the roadway inside and outside of the underpass. The height, width, and length of the underpass determines the amount of light penetration from the exterior.

Lighting of independent sidewalks or shared use paths should be evaluated on a project specific basis. Considerations include the likelihood of night time use, the role of the facility in the community's bicycle and pedestrian network, and whether alternatives are available for night time travel.

## G.1 Daytime Lighting

A gradual decrease in the illumination level from day time level on the roadway, sidewalk or path to the underpass should be provided. Supplemental day time lighting is normally not needed in underpasses less than 100 feet in length.

## G.2 Night Lighting

The night time illumination level in the underpass should be maintained near the night time level of the approach roadway, sidewalk or path. Due to relatively low luminaire mounting heights, care should be exercised to avoid glare.

# H ADAPTIVE LIGHTING

Some locations such as coastal roadways where sea turtles may be affected, may require lower lighting levels and colors than what might normally be provided. FHWA's publication ***The Guidelines for the Implementation of Reduced Lighting on Roadways*** describes a process by which an agency or a lighting designer can select the required lighting level for a road or street and implement adaptive lighting for a lighting installation or lighting retrofit. This document supplements existing lighting guidelines.

## I OVERHEAD SIGN LIGHTING

It is recommended that the level of illumination for overhead signs not be less than guidelines found in Table 6 – 3 Illuminance and Luminance Levels for Sign Lighting.

**Table 6 – 3**
**Illuminance and Luminance Levels for Sign Lighting***

| Ambient Luminance | Sign Illuminance | | Sign Luminance** | |
|---|---|---|---|---|
| | Footcandles | Lux | Candelas per Square Meter | Candelas per Square Foot |
| Low | 10 - 20 | 100 - 200 | 22 - 44 | 2.2 – 4.4 |
| Medium | 20 - 40 | 200 - 400 | 44 - 89 | 4.4 – 8.9 |
| High | 40 - 80 | 400 - 800 | 89 - 78 | 89 – 178 |

*Adapted from The IESNA Lighting Handbook, Reference & Application, 9th Edition, Illuminating Engineering Society of North America.

**Based upon a maintained reflectance of 70 percent for white sign letters.

## J MAINTENANCE

A program of regular preventive maintenance should be established to ensure levels of illumination do not go below required values. The program should be coordinated with lighting design to determine the maintenance period. Factors for consideration include a decrease in lamp output, luminaire components becoming dirty, and the physical deterioration of the reflector or refractor. The maintenance of roadway lighting should be incorporated in the overall maintenance program specified in ***Chapter 10 – Maintenance and Resurfacing***.

## K LIGHT POLES

Light poles should not be placed in the sidewalk when adequate right of way is available beyond the sidewalk. Placement of lighting structures and achieved illumination may be limited by existing conditions such as driveways, overhead and underground utilities, drainage structures, and availability of right of way.

Light poles should not be placed so as to provide a hazard to out of control vehicles. Non-frangible light poles should be placed outside of the clear zone. They should be as far removed from the travel lane as possible or behind adequate guardrail or other barriers. Light poles should be placed on the inside of the curves when feasible. Foundations or light poles and rigid auxiliary lighting components that are not behind suitable barriers should be constructed flush with or below the ground level.

The use of high mast lighting should be considered, particularly for lighting interchanges and other large plaza areas. This use tends to produce a more uniform illumination level, reduces glare, and allows placement of the light poles farther from the roadway. Additional emphasis lighting should be considered to illuminate specific and desired pedestrian crossings.

The placement of light poles should not interfere with the driver's sight distance or visibility of signs, signals, or other traffic control devices. Further criteria regarding the placement of roadside structures, including light poles, is specified in ***Chapter 4 – Roadside Design***.

## L REFERENCES

The publications referenced in this chapter can be obtained at the following web sites.

- Roadway Lighting, ANSI/RP-8-14
  http://www.ies.org/store/product/roadway-lighting-ansiies-rp814-1350.cfm

- AASHTO - Roadway Lighting Design Guide (October 2005)
  https://bookstore.transportation.org

- Guidelines for the Implementation of Reduced Lighting on Roadways
  PUBLICATION NO. FHWA-HRT-14-050 JUNE 2014
  http://www.fhwa.dot.gov/publications/research/safety/14050/14050.pdf

# CHAPTER 7

# RAIL-HIGHWAY CROSSINGS

## TABLES



## FIGURES

# CHAPTER 7

# RAIL-HIGHWAY CROSSINGS

## A INTRODUCTION

The basic design for grade crossings should be similar to that given for highway intersections in ***Chapter 3** – **Geometric Design***. Rail-highway grade crossings should be limited in number and should, where feasible, be accomplished by grade separations. Where at-grade crossings are necessary, adequate traffic control devices and proper crossing design are required to limit the probability of crashes.

## B OBJECTIVE AND PRIORITIES

The primary objective in the design, construction, maintenance, and reconstruction of rail-highway crossings is to provide safety for both rail and roadway vehicles in a feasible and efficient manner. The achievement of this objective may be realized by utilizing the following techniques in the listed sequence of priority.

### B.1 Conflict Elimination

The elimination of at grade rail-highway conflicts is the most desirable procedure for promoting safe and efficient traffic operations. This may be accomplished by the closing of a crossing or by utilizing a grade separation structure.

### B.2 Hazard Reduction

The design of new at-grade crossings should consider the objective of hazard reduction. In addition, an effective program of reconstruction should be directed towards reducing crash potential at existing crossings.

The regulation of intersections between railroads and all public streets and highways in Florida is vested in the ***Florida Administrative Code, (Rule Chapter 14-57: Railroad Safety and Clearance Standards, and Public Railroad-Highway Grade Crossings***. This rule contains minimum requirements for all new grade crossings.

The Department's rail office has other documents available that contain additional guidance for the design, reconstruction, and upgrading of existing rail-highway grade crossings, and may be contacted for further information.

## C RAIL-HIGHWAY GRADE CROSSING NEAR OR WITHIN PROJECT LIMITS

Federal-aid projects must be reviewed to determine if a rail-highway grade crossing is within the limits of or near the terminus of the project. If such rail-highway grade crossing exists, the project must be upgraded to meet the requirements of the ***Manual on Uniform Traffic Control Devices (2009 Edition with Revision Numbers 1 and 2, May 2012) (MUTCD)*** in accordance with ***Title 23, United States Code (U.S.C.), Chapter 1, Section 109(e)*** *and* ***23** C.F.R. 646.214(b).*

These requirements are located in ***Chapter 8*** of the ***MUTCD***. "Near the terminus" is defined as being either of the following:

- If the project begins or ends between the crossing and the MUTCD-mandated advanced placement distance for the advanced (railroad) warning sign. See ***MUTCD, Table 2C-4 (Condition B, Column "0" mph)*** for this distance.
- An intersection traffic signal within the project is linked to the crossing's flashing light signal and gate.

# D DESIGN OF RAIL-HIGHWAY CROSSINGS

The primary requirement for the geometric design of a grade crossing is that it provides adequate sight distance for the motorist to make an appropriate decision as to stop or proceed at the crossing.

## D.1 Sight Distance

The minimum sight distance requirements for streets and highways at rail-highway grade crossings are similar to those required for highway intersections (***Chapter 3 – Geometric Design***).

### D.1.a Stopping Sight Distance

The approach roadways at all rail-highway grade crossings should consider stopping sight distance no less than the values given in ***Chapter 3, Table 3 – 3, Stopping Sight Distances*** for the approach to stop signs. This distance shall be measured to a stopping point prior to gates or stop bars at the crossing, but not less than 15 feet from the nearest track. All traffic control devices shall be visible from the driver eye height of 3.50 feet.

### D.1.b Sight Triangle

At grade crossings without train activated signal devices, a sight triangle should be provided.

The provision of the capability for defensive driving is an important aspect of the design of rail-highway grade crossings. An early view of an approaching train is necessary to allow the driver time to decide to stop or to proceed through the crossing.

The size of this sight triangle, which is shown in Figure 7 – 1 Visibility Triangle at Rail-Highway Grade Crossings, is dependent upon the train speed limit, the highway design speed, and the highway approach grade. The minimum distance along the highway ($d_H$), includes the requirements for stopping sight distance, the offset distance (D) from the edge of track to the stopped position (15 feet), and the eye offset ($d_e$) from the front of vehicles (8 feet); (Figure 7 – 1, Case A). The required distance ($d_T$) along the track, given in Table 7 – 1, Sight Distance at Rail-Highway Grade Crossings, is necessary to allow a vehicle to stop or proceed across the track safely. Where the roadway is on a grade, the lateral sight distance ($d_T$) along the track should be increased as noted (Table 7 – 1). This lateral sight distance is desirable at all crossings. In other than flat terrain it may be necessary to rely on speed control signs and devices and to predicate sight distance on a reduced speed of operation. This reduced speed should never be less than 15 mph and preferably 20 mph.

### D.1.c Crossing Maneuvers

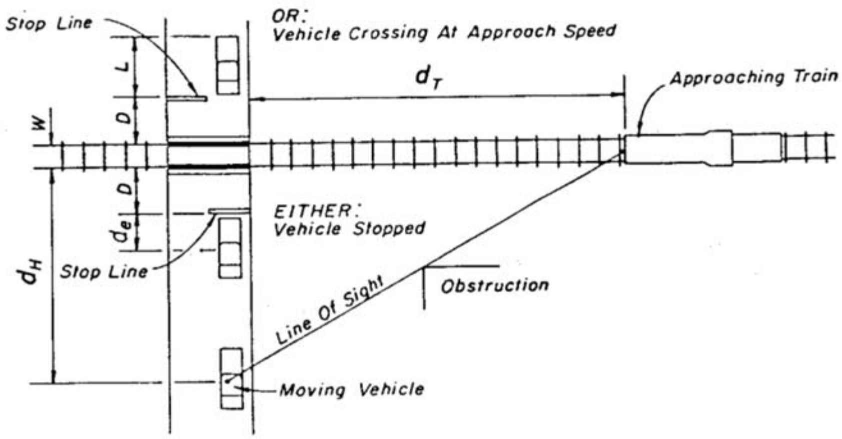
The sight distance required for a vehicle to cross a railroad from a stop is essentially the same as that required to cross a highway intersection as given in ***Chapter 3 – Geometric Design***.

An adequate clear distance along the track in both directions should be provided at all crossings. This distance, when used, shall be no less than the values obtained from Figure 7 – 1 Visibility Triangle at Rail-Highway Grade Crossings and Table 7 – 1 (Case B), Sight Distance at Rail-Highway Grade Crossings. Due to the greater stopping distance required for trains, this distance should be increased wherever possible.

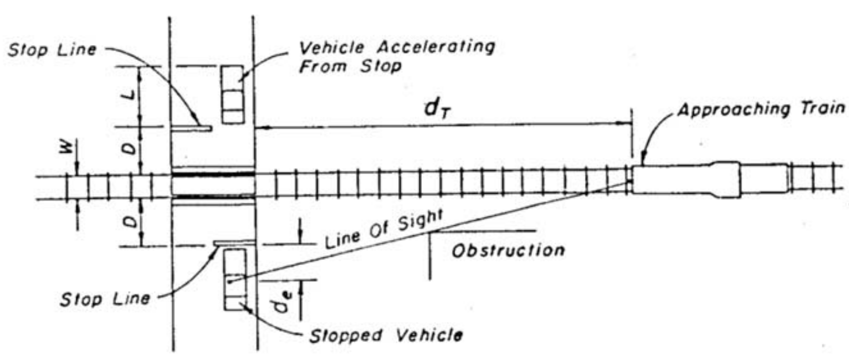
The crossing distance to be used shall include the total width of the tracks, the length of the vehicle, and an initial vehicle offset. This offset shall be at least 10 feet back from any gates or flashing lights, but not less than 15 feet from the nearest track. The train speed used shall be equal to or greater than the established train speed limit.

The setback for determining the required clear area for sight distance should be at least 10 feet more than the vehicle offset. Care should be exercised to ensure signal supports and other structures at the crossing do not block the view of drivers preparing to cross the tracks.

**Figure 7 – 1**
**Visibility Triangle at Rail-Highway Grade Crossings**




CASE **A**
APPROACHING VEHICLE TO SAFELY CROSS OR STOP AT RAILROAD CROSSING




CASE **B**
VEHICLE DEPARTING FROM STOPPED POSITION TO SAFELY CROSS RAILROAD TRACK

For $d_H$ and $d_T$ values and crossing conditions see Table **7-1.**

## Table 7 – 1
## Sight Distance at Rail-Highway Grade Crossings

| Design Sight Distances For Combinations Of Train And Highway Vehicle Speeds<br>Conditions: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Single Track 90° Crossing<br>Design Vehicle WB-67 (L=73.5' $d_e$=8')<br>Flat Highway Grades | | | | Track Width (W) = 5'<br>Vehicle Stop Position (D) = 15'<br>No Train Activated Warning Devices | | | | |
| TRAIN SPEED (mph) | CASE B VEHICLE DEPARTURE FROM STOP | CASE A MOVING VEHICLE | | | | | | |
| | VEHICLE SPEED (mph) | | | | | | | |
| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| | $d_t$ (feet)<br>SIGHT DISTANCE ALONG RAILROAD TRACK | | | | | | | |
| 10 | 255 | 155 | 110 | 102 | 102 | 106 | 112 | 119 |
| 20 | 509 | 310 | 220 | 203 | 205 | 213 | 225 | 239 |
| 30 | 764 | 465 | 331 | 305 | 307 | 319 | 337 | 358 |
| 40 | 1019 | 619 | 441 | 407 | 409 | 426 | 450 | 478 |
| 50 | 1274 | 774 | 551 | 509 | 511 | 532 | 562 | 597 |
| 60 | 1528 | 929 | 661 | 610 | 614 | 639 | 675 | 717 |
| 70 | 1783 | 1084 | 771 | 712 | 716 | 745 | 787 | 836 |
| 80 | 2038 | 1239 | 882 | 814 | 818 | 852 | 899 | 956 |
| 90 | 2292 | 1394 | 992 | 915 | 920 | 958 | 1012 | 1075 |
| 100 | 2547 | 1548 | 1102 | 1017 | 1023 | 1064 | 1124 | 1194 |
| 110 | 2802 | 1703 | 1212 | 1119 | 1125 | 1171 | 1237 | 1314 |
| 120 | 3057 | 1858 | 1322 | 1221 | 1227 | 1277 | 1349 | 1433 |
| 130 | 3311 | 2013 | 1433 | 1322 | 1329 | 1384 | 1461 | 1553 |
| $d_H$ (feet)<br>SIGHT DISTANCE ALONG HIGHWAY | | | | | | | | |
| | | 69 | 135 | 220 | 324 | 447 | 589 | 751 |

(Continued on Next Page)

**Table 7 – 1**
**Sight Distance at Rail-Highway Grade Crossings**
**(continued)**

Source: Developed from ***Table 9 – 32, A Policy on Geometric Design of Highway and Streets, AASHTO (2011).***

Notes: 1) Sight distances are required in all quadrants of the crossing.

2) Corrections must be made for conditions other than shown in the table, such as, multiple rails, skewed angle crossings, ascending and descending grades, and curvature of highways and rails. For condition adjustments and additional information refer to Railroad-Highway Grade Crossings under ***Chapter 9*** of "***A Policy on Geometric Design of Highways and Streets", AASHTO (2011)***. Additional information is available on FHWA's website for ***Highway-Rail Grade Crossing Surfaces*** and ***NCHRP Synthesis 250 Highway – Rail Grade Crossing Surfaces, TRB, (1998).***"

## D.2 Approach Alignment

The alignment of the approach roadways is a critical factor in developing a safe grade crossing. The horizontal and vertical alignment, and particularly any combination thereof, should be as gentle as possible.

### D.2.a Horizontal Alignment

The intersection of a highway and railroad should be made as near to the right angle (90 degrees) as possible. Intersection angles less than 70 degrees should be avoided. The highway approach should, if feasible, be on a tangent, because the use of a horizontal curve tends to distract the driver from a careful observation of the crossing. The use of superelevation at a crossing is normally not possible, since this would prevent the proper grade intersection with the railroad.

### D.2.b Vertical Alignment

The vertical alignment of the roadway on a crossing is an important factor in safe vehicle operation. The intersection of the tracks and the roadway should constitute an even plane. All tracks should, preferably, be at the same elevation, thus allowing a smooth roadway through the crossing. Where the railroad is on a curve with superelevation, the vertical alignment of the roadway shall coincide with the grade established by the tracks.

Vertical curvature on the crossing should be avoided. This is necessary to limit vertical motion of the vehicle.

The vertical alignment of the approach roadway should be adjusted when rail elevations are raised to prevent abrupt changes in grade and entrapment of low clearance vehicles

The roadway approach to crossing should also coincide with the grade established by the tracks. This profile grade, preferably zero, should be extended a reasonable distance (at least two times the design speed in feet) on each side of the crossing. Where vertical curves are required to approach this section, they should be as gentle as possible. The length of these vertical curves shall be of sufficient length to provide the required sight distance.

## D.3 Highway Cross Section

Preserving the continuity of the highway cross section through a grade crossing is important to prevent distractions and to avoid hazards at an already dangerous location.

### D.3.a Pavement

The full width of all travel lanes shall be continued through grade crossings. The crown of the pavement shall be transitioned gradually to meet the cross sectional grade of the tracks. This pavement cross slope transition shall be in conformance with the requirements for superelevation runoff. The lateral and longitudinal pavement slopes should be designed to direct drainage away from the tracks.

### D.3.b Shoulders

All shoulders shall be carried through rail-highway grade crossings without interruption.

The use of full-width paved shoulders is required at all new crossings to maintain a stable surface for emergency maneuvers. The shoulders should be paved a minimum distance of 50 feet on each side of the crossing, measured from the outside rail. It is desirable to pave 100 feet on either side to permit bicycles to exit the travel lane, slow for their crossing, and then make an adequate search before selecting a gap for a return to the travel lane. See ***Chapter 3, Table 3 – 11 Shoulder Widths for Rural Highways*** for further information on shoulder width.

### D.3.c Medians

It is recommended that the full median width on divided highways should be continued through the crossing. The median should be contoured to provide a smooth transition on the tracks.

A raised median is the ideal deterrent to discourage motorists from driving around the gates to cross the tracks or making a U-turn prior to the tracks. Flush medians should have channelization devices as a deterrent. Railroad signals and gate assemblies should be installed in the median only when gate arms of 36 feet will not adequately span the approach roadway.

**Figure 7 – 2 Flush Median Channelization Devices**

*Alexander Street, SR 39A, Plant City, FL 1*

### D.3.d Sidewalks and Shared Use Paths

To provide an accessible route for pedestrians at grade rail-highway crossings, new or existing sidewalks and shared use paths shall be continued across the rail crossing. The surface of the crossing shall be:

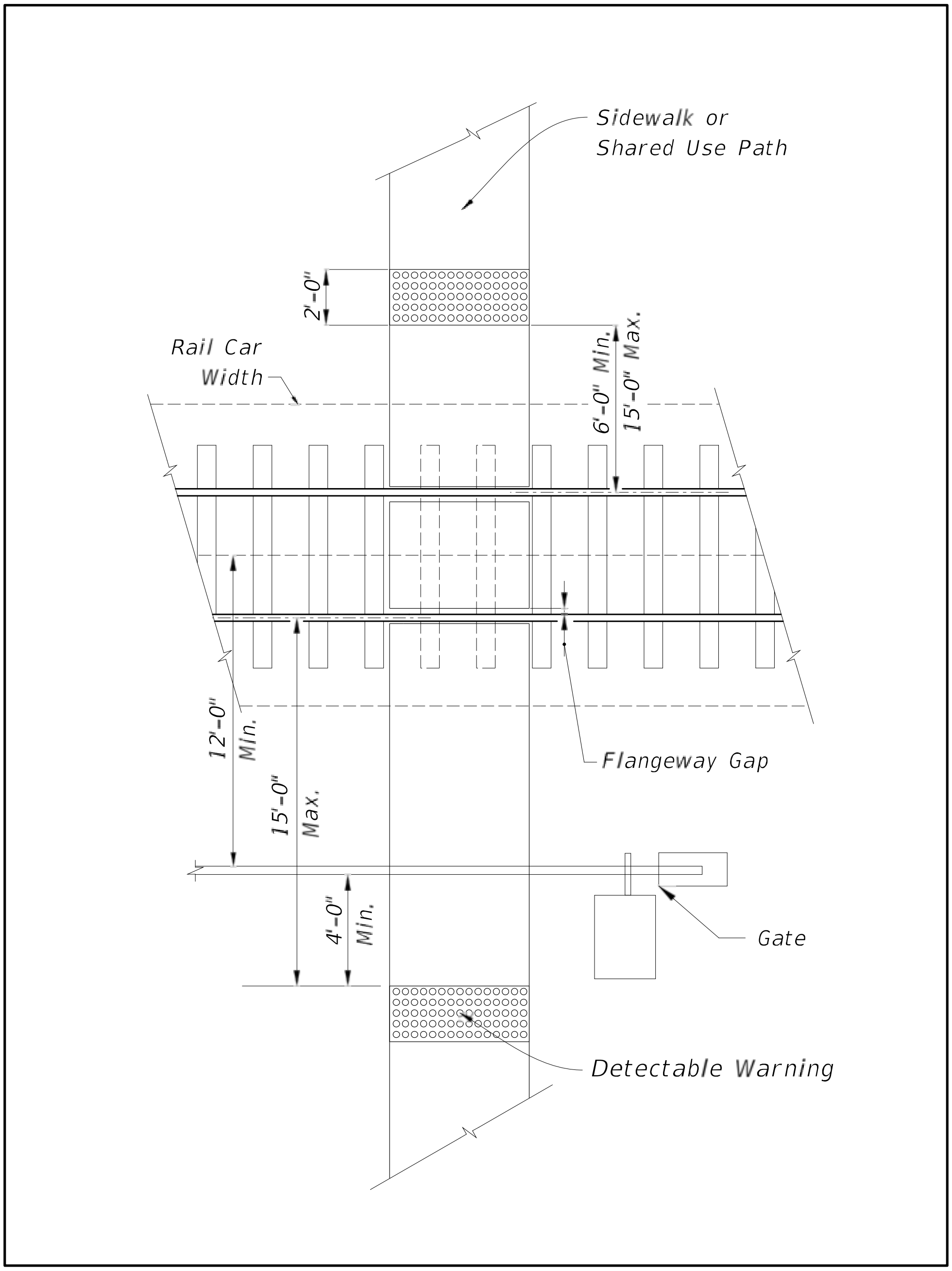
- firm, stable and slip resistant,
- level and flush with the top of rail at the outer edges of the rails, and
- area between the rails align with the top of rail.

Detectable warnings shall be placed on each side of the rail-highway crossing, extend 2.0 feet in the direction of pedestrian travel and the full width across the sidewalk or shared use path, as shown in Figure 7 – 3 Pedestrian Crossings.

The edge of the detectable warning nearest the rail crossing shall be 6.0 to 15.0 feet from the centerline of the nearest rail. Where pedestrian gates are provided, detectable warnings shall be placed a minimum of 4.0 feet from the side of the gates opposite the rail, and within 15.0 feet of the centerline of the nearest rail.

If traffic control signals are in operation at a crossing that is used by pedestrians or bicyclists, an audible device such as a bell shall also be provided and operated in conjunction with the traffic control signals. See *MUTCD, Chapters 8B and 8C* for further information and to determine if additional signals, signs, or pedestrian gates should be included. See ***MUTCD, Chapter 8D*** for additional information on designing crossings for shared use paths.

## Figure 7 – 3 Pedestrian Crossings

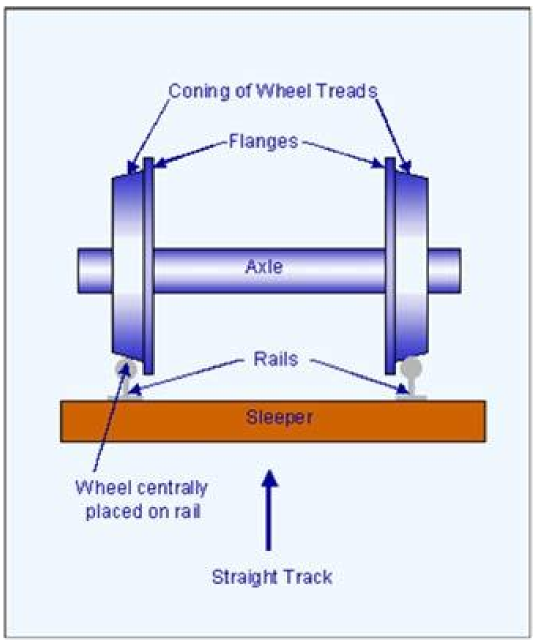


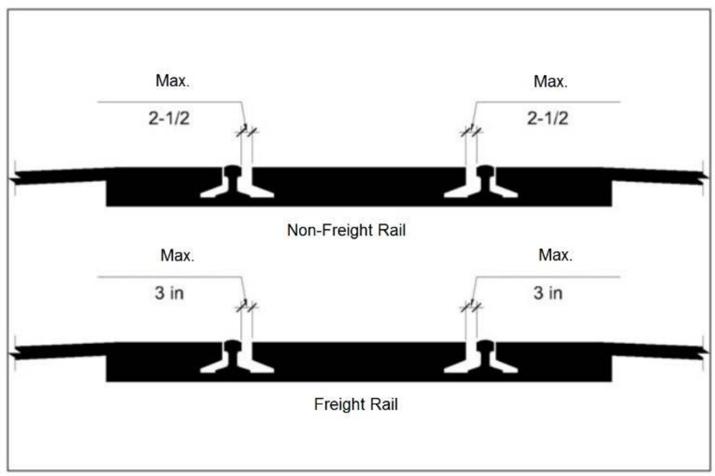

Note: Pedestrian gates may be installed on the outside of the sidewalk/shared use path or in the utility strip.

Flangeway gaps are necessary to allow the passage of train wheel flanges; however, they pose a potential hazard to pedestrians who use wheelchairs because the gaps can entrap the wheelchair casters. Flangeway gaps at pedestrian at-grade rail crossings shall be 2 ½" maximum on non-freight rail track and 3" maximum on freight rail track.

Figure 7 – 4 Flangeways and Flangeway Gaps illustrates where the flanges are located on the wheel, how they interact with the rails, and the maximum gap allowed.

**Figure 7 – 4 Flangeways and Flangeway Gaps**




See ***Chapter 8 – Pedestrian Facilities*** and ***Chapter 9 – Bicycle Facilities*** for further information on designing sidewalks and shared use paths. The ***2006 Americans with Disabilities Act – Standards for Transportation Facilities*** and the ***2012 Florida Accessibility Code*** impose additional requirements for the design and construction of pedestrian facilities.

#### D.3.e Roadside Clear Zone

Although it is often not practical to maintain the full width of the roadside clear zone, the maximum clear area feasible should be provided. This clear zone shall conform to the requirements for slope and change in grade for roadside clear zones.

#### D.3.f Auxiliary Lanes

Auxiliary lanes are permitted but not encouraged at signalized rail-highway grade crossings that have a large volume of bus or truck traffic required to stop at all times. These additional lanes should be restricted for the use of these stopping vehicles. The approaches to these auxiliary lanes shall be designed as storage for deceleration lanes. The exits shall be designed as acceleration lanes.

### D.4 Roadside Design

The general requirements for roadside design given in ***Chapter 3 – Geometric Design*** and ***Chapter 4 – Roadside Design***, should be followed at rail-highway grade crossings. Supports for traffic control devices may be required within the roadside recovery area. Due to the structural requirements and the necessity for continuous operation, the use of a breakaway design is not recommended. The use of a guardrail or other longitudinal barrier is also not recommended, because an out of control vehicle would tend to be directed into the crossing.

In order to reduce the hazard to errant vehicles, all support structures should be placed as far from the traveled way as practicable.

## D.5 Vertical Clearance

Minimum vertical clearances for grade separated rail-highway crossings are shown in Table 7 – 2 Minimum Vertical Clearances for New Bridges. Minimum vertical clearance is the least distance between the bottom of the superstructure and the top of the highest rail utilized anywhere within the horizontal clearance zone.

**Table 7 – 2 Minimum Vertical Clearances for New Bridges**

| Facility Type | Clearance |
|---|---|
| Railroad over Roadway | 16'-6" |
| Roadway over Railroad[1] | 23'-6" |
| Pedestrian over Railroad[1] | 23'-6" |

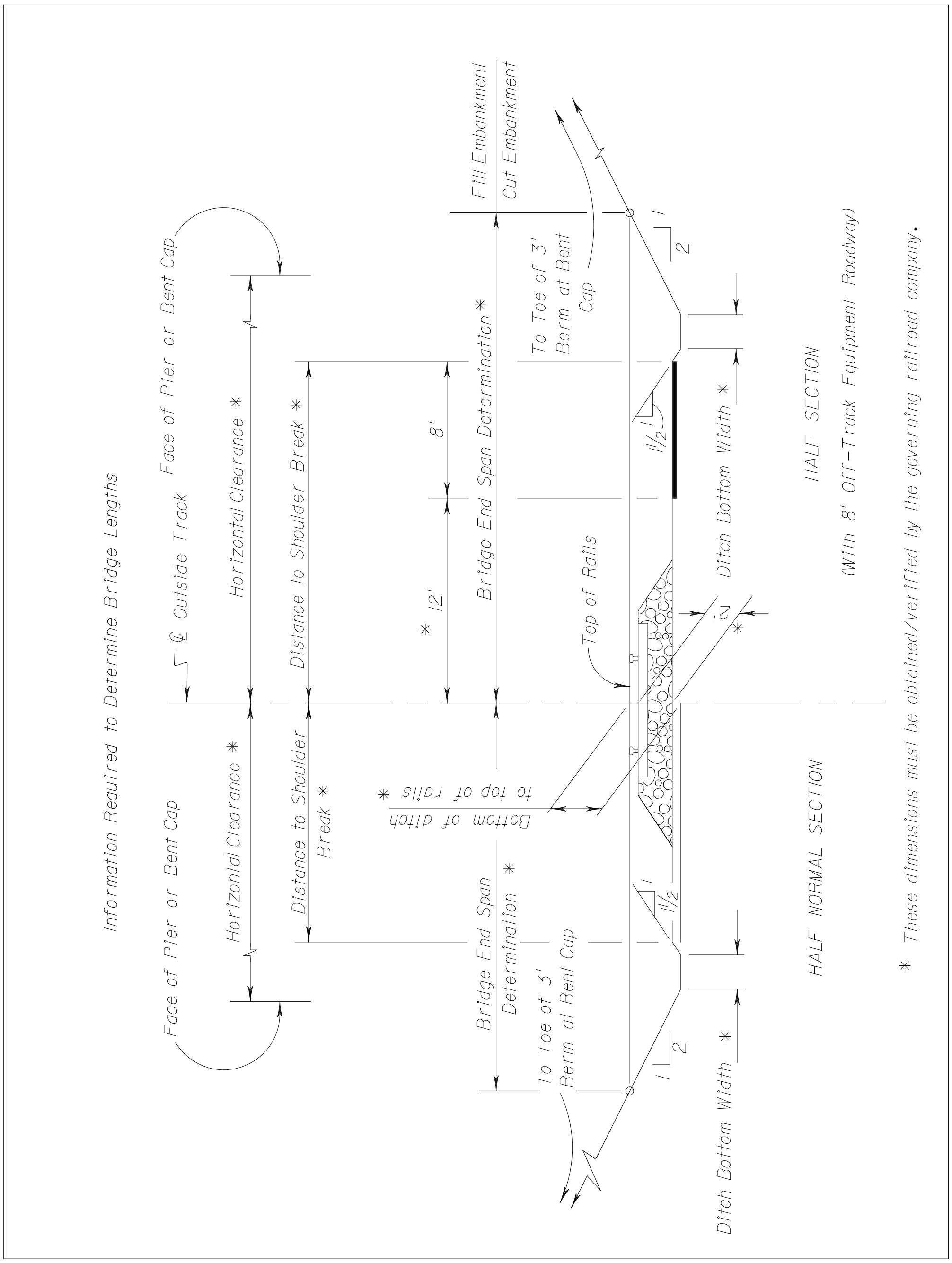
1. Over High Speed Rail Systems, see the latest version of ***American Railway Engineering and Maintenance-of-Way Association (AREMA)*** guidelines, or the design office of the high-speed rail line of interest for specific guidelines and specifications. Over Electrified Railroad, the minimum vertical clearance shall be 24 feet 3 inches. (See ***Department Topic No. 000-725-003: South Florida Rail Corridor Clearance***.)

For any construction affecting existing bridge clearances (e.g., bridge widenings or resurfacing) vertical clearances less than 16' - 0" shall be maintained or increased. If reducing the design vertical bridge clearance to a value between 16' - 0" and 16' - 2", the design vertical clearance dimension in the plans shall be stated as a minimum.

## D.6 Horizontal Clearance

Horizontal clearances shall be measured in accordance with Figure 7 – 5 Track Section. The governing railroad company occasionally may accept a waiver from normal clearance requirements if justified; i.e., for designs involving widening or replacement of existing overpasses. The Department's District Rail Coordinator should be consulted if such action is being considered for FDOT owned rail corridors. For other rail crossings, coordinate with the owner of the rail corridor.

# Figure 7 – 5 Track Section



The minimum horizontal clearances measured from the centerline of outermost existing or proposed tracks to the face of pier cap, bent cap, or any other adjacent structure are shown in Table 7 – 3 Horizontal Clearances for Railroads but must be adjusted for certain physical features and obstructions such as track geometry and physical obstructions.

**Table 7 – 3 Horizontal Clearances for Railroads**

| Minimum Clearance Requirements | Normal Section[1] | With 8' Required Clearance for Off-Track[2] | Temporary Falsework Opening |
|---|---|---|---|
| With Crash Walls | 18 ft. | 22 ft. | 10 ft. |
| Without Crash Walls | 25 ft. | 25 ft. | N/A |

[1] Any proposed structure over the South Florida Rail Corridor shall be designed and constructed to provide a horizontal clear span of a minimum of 100 feet but not less than 25 feet from the center line of the outermost existing or proposed tracks. (See ***Department Topic No. 000-725-003-j: South Florida Rail Corridor Clearance.***)

[2] The additional 8 ft. horizontal clearance for off-track equipment shall be provided only when specifically requested in writing by the railroad.

### D.6.a Adjustments for Track Geometry

When the track is on a curve, the minimum horizontal clearance shall be increased at a rate of 1.5 inches for each degree of curvature. When the track is superelevated, clearances on the inside of the curve will be increased by 3.5 inches horizontally per inch of superelevation. For extremely short radius curves, the AREMA requirements shall be consulted to assure proper clearance.

### D.6.b Adjustments for Physical Obstructions

Columns or piles should be kept out of the ditch to prevent obstruction of drainage. Horizontal clearance should be provided to avoid the need for crash walls unless extenuating circumstances dictate otherwise.

Figure 7 – 5 Track Sections shows horizontal dimensions from the centerline of track to the points of intersection of a horizontal plane at the rail elevation with the embankment slope. These criteria may be used to establish the preliminary bridge length, which normally is also the length of bridge eligible for FHWA participation; however, surrounding topography, hydraulic conditions, and economic or structural considerations may warrant a decrease or an increase of these dimensions. These dimensions must be coordinated with the governing railroad company.

The ***Department's Structures Design Guidelines, Section 2.6.7*** provide additional information on the design of structures over or adjacent to railroad and light rail tracks.

## D.7 Access Control

The general criteria for access control in ***Chapter 3 – Geometric Design*** for streets and highways should be maintained in the vicinity of rail-highway grade crossings. Private driveways should not be permitted within 150 feet, nor intersections within 300 feet, of any grade crossing.

## D.8 Parking

No parking shall be permitted within the required clear area for the sight distance visibility triangle.

## D.9 Traffic Control Devices

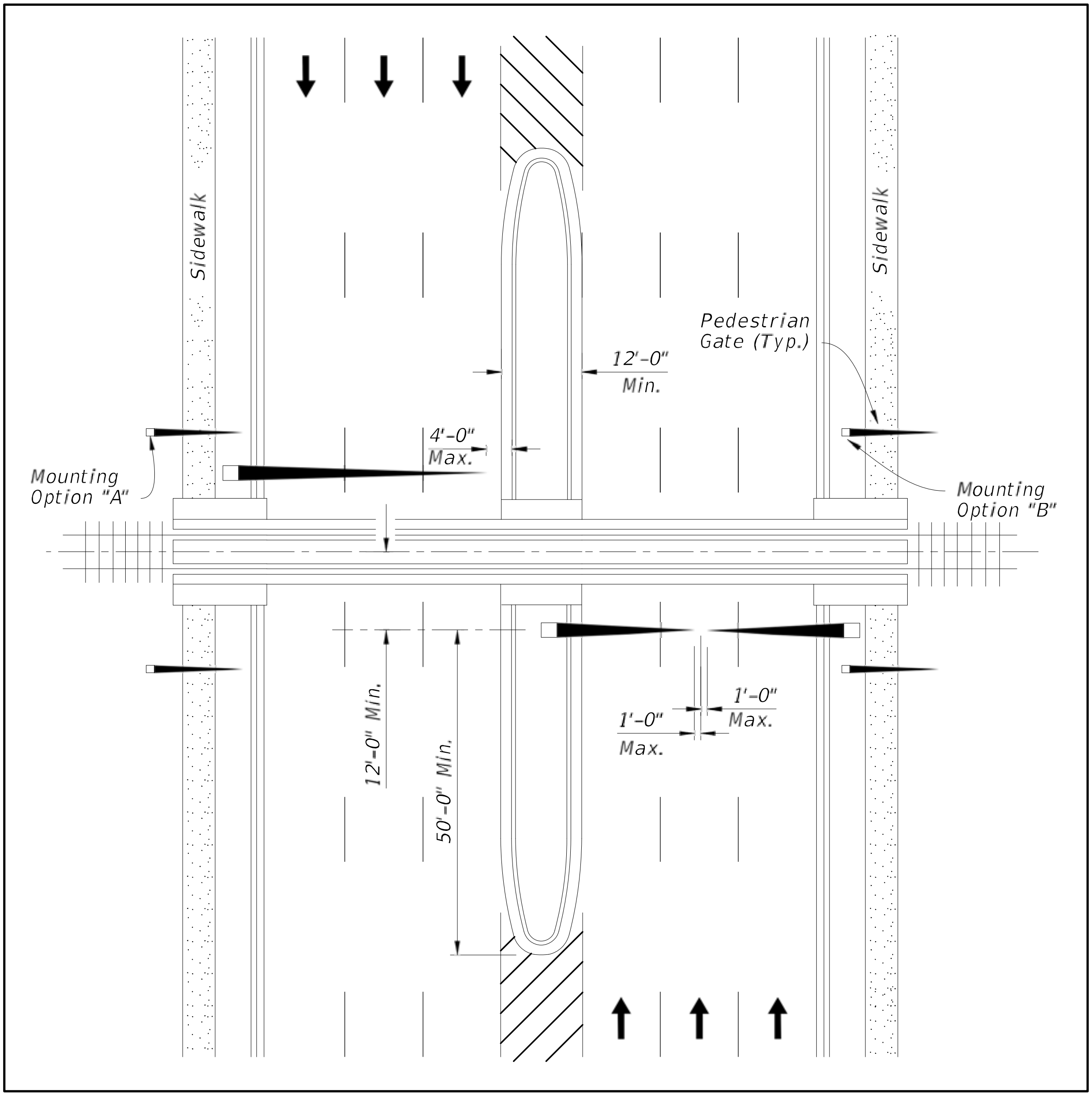
The proper use of adequate advance warning and traffic control devices is essential for all grade crossings. Advance warning should include pavement markings and two or more signs on each approach. Each new crossing should be equipped with train-activated flashing signals.

Automatic gates, when used, should ideally extend across all lanes, but shall at least block one-half of the inside travel lane. It is desirable to include crossing arms across sidewalks and shared use paths.

Traffic control devices shall meet the requirements of the ***MUTCD***. See Section E of this chapter for additional requirements for traffic control devices in Quiet Zones.

Figure 7 – 6 Median Signal Gates for Multilane Curbed Sections provides an example of gate installation when a median is present.

**Figure 7 – 6 Median Signal Gates for Multilane Curbed Sections**



## D.10 Rail-Highway Grade Crossing Surface

Each crossing surface should be compatible with highway user requirements and railroad operations at the site. When installing a new rail-highway crossing or reworking an existing at-grade crossing, welded rail should be placed the entire width from shoulder point to shoulder point. Surfaces should be selected to be as maintenance free as possible.

## D.11 Roadway Lighting

The use of roadway lighting at grade crossings should be considered to provide additional awareness to the driver. Illumination of the tracks can also be a beneficial safety aid.

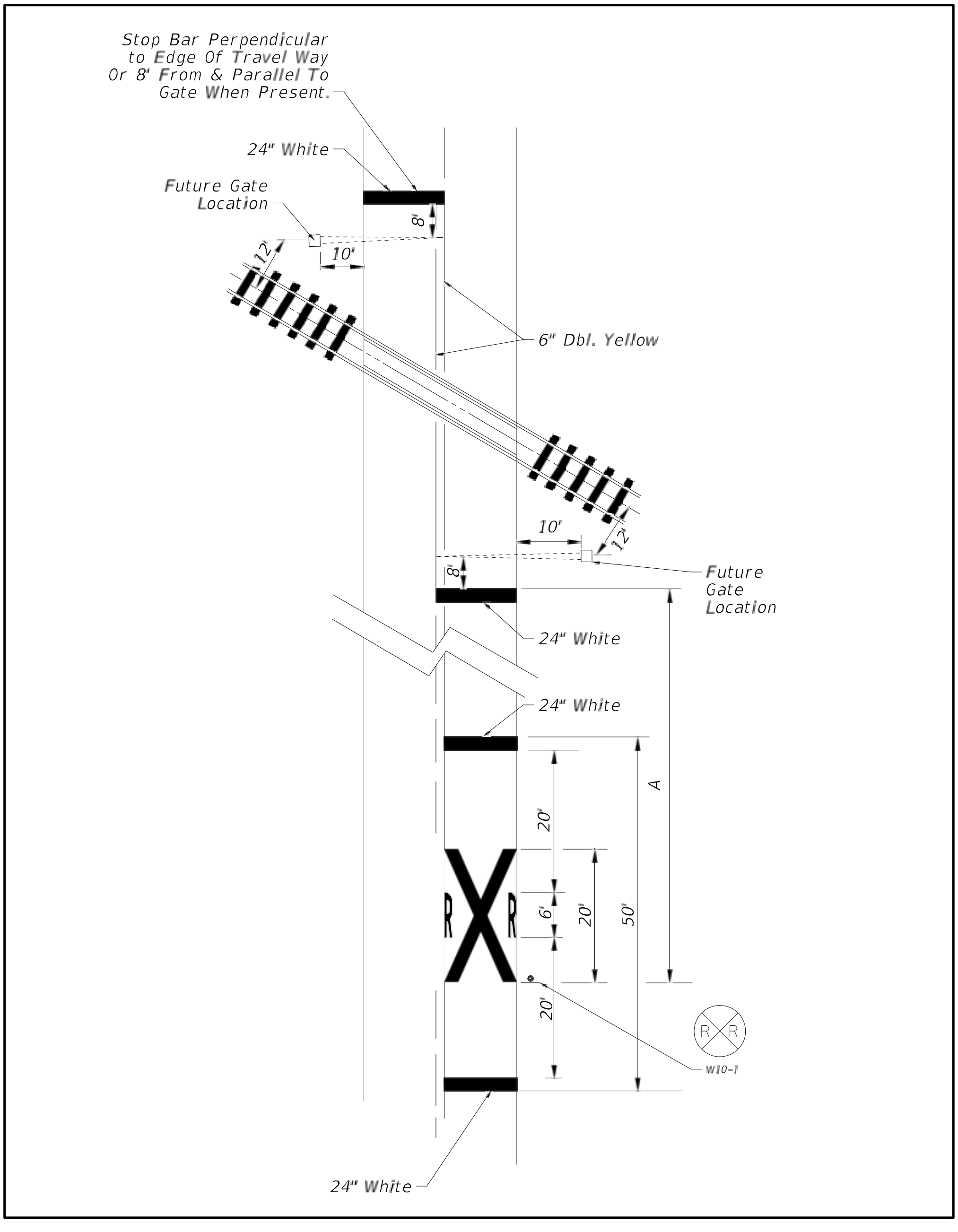
## D.12 Crossing Configuration

Recommended layouts for grade crossings are shown in Figures 7 – 7 Passive Rail-Highway Grade Crossing Configuration and 7 – 8 Active Rail-Highway Grade Crossing Configuration. The distance “A” in the Figures is determined by speed and shown in the ***MUTCD, Table 2C – 4. Guidelines for the Advance Placement of Warning Signs***. Although the design of each grade crossing must be "tailored" to fit the existing situation, the principles given in this section should be followed in the design of all crossings. Additional information on the design of rail-highway crossings can be found in the Department’s ***Design Standards, Index 17881 and 17882***.

Passive rail-highway grade crossings include traffic control devices that provide static messages of warning, guidance, and, in some instances, mandatory action for the driver. *(Source: **FHWA Railroad-Highway Grade Crossing Handbook**)*

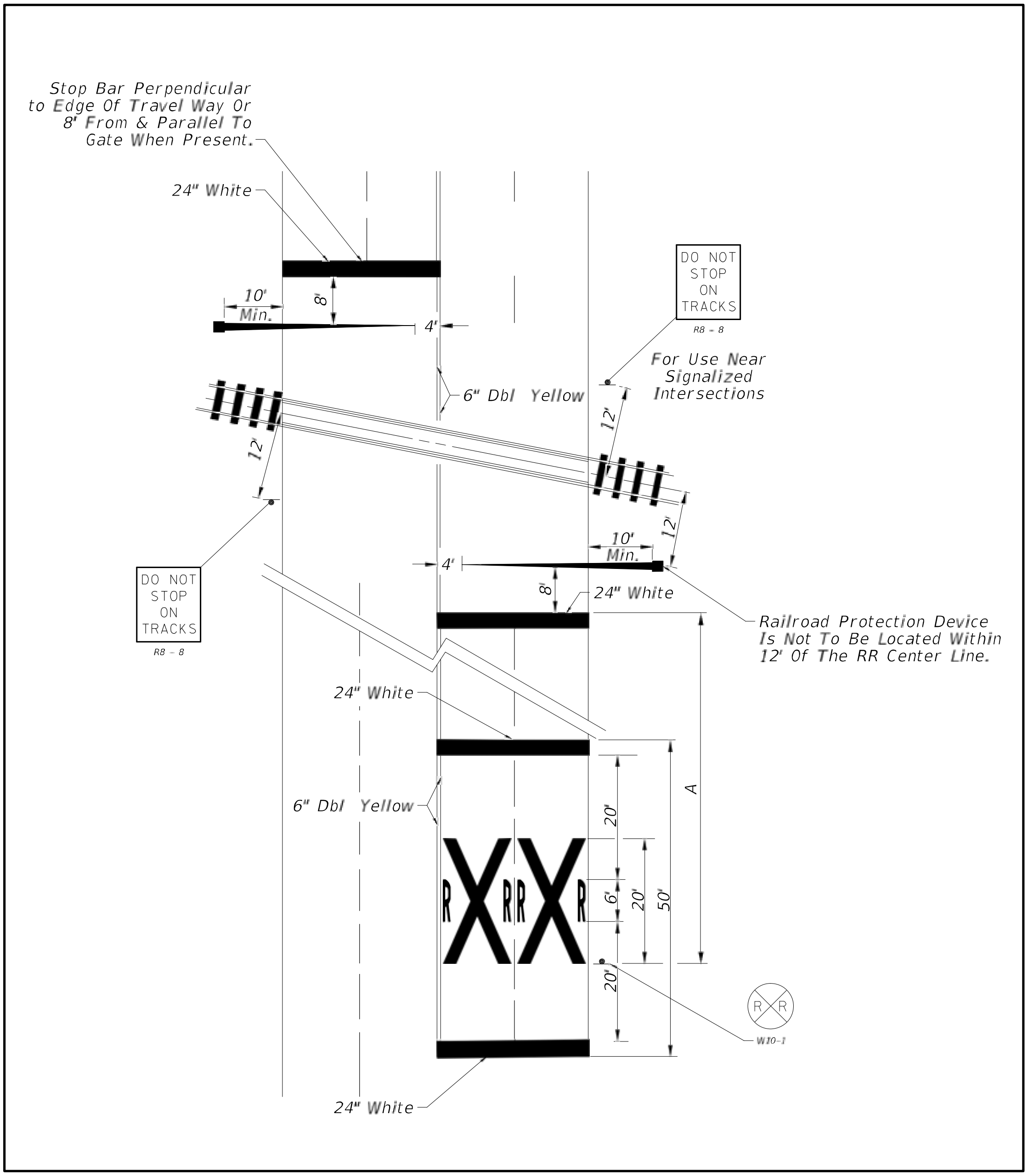
Active rail-highway grade crossings include traffic control devices that give advance notice of the approach of a train. *(Source: **FHWA Railroad-Highway Grade Crossing Handbook**).*

## Figure 7 – 7 Passive Rail-Highway Grade Crossing Configuration




Note: The distance “A” is determined by speed and shown in the ***MUTCD, Table 2C – 4. Guidelines for the Advance Placement of Warning Signs***.

## Figure 7 – 8 Active Rail-Highway Grade Crossing Configuration




Note: The distance “A” is determined by speed and shown in the ***MUTCD, Table 2C – 4. Guidelines for the Advance Placement of Warning Signs***.

## E QUIET ZONES

Quiet Zone means a segment of a rail line that includes public rail-highway crossings at which locomotive horns are not routinely sounded. The Federal Railroad Administration (FRA) has established guidelines the applying jurisdiction must follow for approval of quiet zones. Applying entities can go to the FRA's website and the ***Code of Federal Regulations (CFR), Title 49, Subtitle B, Chapter II, Part 222*** for further information on the process for approval of Quiet Zones.

Coordinate with the Department's District Rail Coordinator to determine if crossings are located within designated Quiet Zones for State owned rail corridors or crossings of state highways. State owned rail corridors include the ***Central Florida Rail Corridor*** and ***South Florida Rail Corridor***. For other rail crossings, coordinate with the local government who maintains the crossing roadway, sidewalk or shared use path to determine if the location has been approved by the FRA for a Quiet Zone.

For a crossing within a Quiet Zone that requires supplemental safety measures, approved supplemental safety measures include:

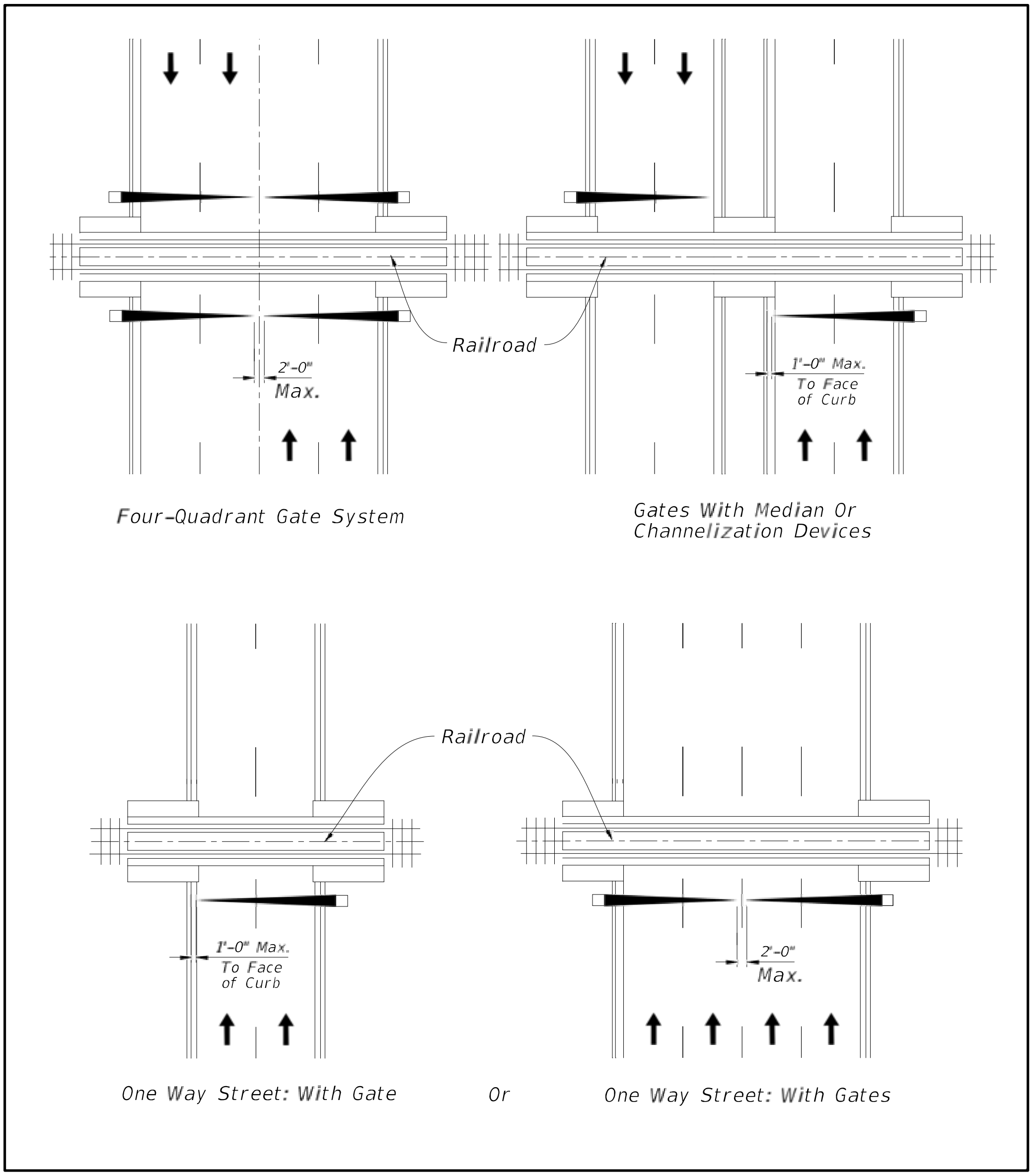
- Temporary closure of a public railroad-highway-rail grade crossing;
- Four-quadrant gate systems;
- Gates with medians or channelization devices;
- One way street with gate(s); and
- Permanent closure of a public highway-rail grade crossing.

The ***CFR, Title 49, Chapter II, Part 222, Appendix A, Approved Supplemental Safety Measures*** provides additional information on the design of Quiet Zones to meet federal approval. The ***CFR*** also requires that any traffic control device and its application where used as part of a Quiet Zone shall comply with all applicable provisions of the ***MUTCD.*** See ***MUTCD, Part 8, Traffic Control for Railroad and Light Rail Transit Grade Crossings*** for further information. Pedestrian gates, audible device, and detectable warnings are required when a sidewalk or shared use path is present or proposed.

For Quiet Zones that cross state owned rail corridors, the Department's ***Plans Preparation Manual, Volume 1, Chapter 6*** provides additional design criteria.

Figure 7 – 9 Gate Configurations for Quiet Zones illustrates the maximum gap allowed for gates at rail-highway crossings within Quiet Zones, based upon ***CFR, Title 49, Chapter II, Part 222.***

**Figure 7 – 9 Gate Configuration for Quiet Zones**



## F HIGH SPEED RAIL

The establishment of high-speed rail service is governed by ***49 U.S. Code 26106 – High-Speed Rail Corridor Development***.

The ***High-Speed Rail (HSR) Strategic Plan*** divides potential operations into four categories or generic descriptions:

- HSR – Express. Frequent express service between major population centers 200 - 600 miles apart, with few intermediate stops. Top speeds of at least 150 mph on completely grade-separated, dedicated rights-of-way (with the possible exception of some shared track in terminal areas). Intended to relieve air and highway capacity constraints.

- HSR – Regional. Relatively frequent service between major and moderate population centers 100 - 500 miles apart, with some intermediate stops. Top speeds of 110 - 150 mph, grade-separated, with some dedicated and some shared track (using positive train control (PTC) technology). Intended to relieve highway and, to some extent, air capacity constraints.

- Emerging HSR. Developing corridors of 100 - 500 miles, with strong potential for future HSR Regional and/or Express service. Top speeds of up to 80 - 110 mph on primarily shared track (eventually using PTC technology), with advanced grade crossing protection or separation. Intended to develop the passenger rail market and provide some relief to other modes.

- Conventional Rail. Traditional intercity passenger rail services of more than 100 miles with as little as 1 to as many as 7 - 12 daily frequencies; may or may not have strong potential for future high-speed rail service. Top speeds of up to 79 mph generally on shared track. Intended to provide travel options and to develop the passenger rail market for further development in the future.

Further information on the implementation of high-speed rail service can be found on the Federal Railroad Administration’s website ***High Speed Rail Overview***.

## G MAINTENANCE AND RECONSTRUCTION

The inspection and maintenance of all features of rail-highway grade crossings shall be an integral part of each highway agency's and railroad company's regular maintenance program (***Chapter 10 – Maintenance And Resurfacing***). Items that should be given a high priority in this program include: pavement stability and skid resistance, clear sight distance, and all traffic control and protective devices.

The improvement of all substandard or hazardous conditions at existing grade crossings is extremely important and should be incorporated into the regular highway reconstruction program. The objective of this reconstruction program should be to upgrade each crossing to meet these standards. The priorities for reconstruction should be based upon the guidelines set forth by the Department.

## H REFERENCES

The following is a list of publications that for further guidance:

- Federal Highway Administration Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007
  http://safety.fhwa.dot.gov/xings/com_roaduser/07010/

- Code of Federal Regulations (CFR), Title 49 Transportation, Part 222, Use of Locomotive Horns at Public Highway-Rail Grade Crossings
  http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title49/49cfr222_main_02.tpl

- The Train Horn Rule and Quiet Zones
  https://www.fra.dot.gov/Page/P0104

- MUTCD, Part 8, Traffic Control for Railroad and Light Rail Transit Grade Crossings
  http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part8.pdf

- The American Railway Engineering and Maintenance-of-Way Association (AREMA)
  https://www.arema.org/

- Florida Administrative Code, (Rule 14-57: Railroad Safety and Clearance Standards, and Public Railroad-Highway Grade Crossings
  https://www.flrules.org/gateway/RuleNo.asp?title=RAILROAD SAFETY AND CLEARANCE STANDARDS, AND PUBLIC RAILROAD-HIGHWAY GRADE CROSSINGS&ID=14-57.011

- Florida Department of Transportation Rail Contacts
  http://www.dot.state.fl.us/rail/contacts.shtm

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# CHAPTER 8

# PEDESTRIAN FACILITIES

# FIGURES

# CHAPTER 8

# PEDESTRIAN FACILITIES

## A INTRODUCTION

Pedestrian facilities shall be given full consideration in the planning and development of transportation facilities, including the incorporation of such facilities into state, regional, and local transportation plans and programs under the assumption that transportation facilities will be used by pedestrians. Pedestrian facilities should be considered in conjunction with the construction, reconstruction, or other significant improvement of any transportation facility. Special emphasis should be given to projects in or within 1 mile of an urban area.

In addition to the design criteria provided in this chapter, the ***2006 Americans with Disabilities Act Standards for Transportation Facilities*** as required by ***49 C.F.R 37.41 or 37.43*** and the ***2012 Florida Accessibility Code for Building Construction*** as required by ***61G20-4.002*** impose additional requirements for the design and construction of pedestrian facilities. Examples of pedestrian facilities include sidewalks, shared use paths, over and under passes, curb ramps, median refuges, and crosswalks.

Each highway agency responsible for a system of streets and highways should establish and maintain a program for implementing pedestrian facilities, and for maintaining existing pedestrian facilities.

## B TYPES OF PEDESTRIAN FACILITIES

There are several ways in which pedestrians can be accommodated in the public right of way.

### B.1 Sidewalks

Sidewalks are walkways parallel to the roadway and designed for use by pedestrians. Sidewalks should be provided along both sides of roadways that are in or within one mile of an urban area. If sidewalks are constructed on the approaches to bridges, they should be continued across the structure. If continuous sidewalks are constructed on only one side of the street, pedestrians should be provided access to facilities and services located on the opposite side of the street. Newly constructed, reconstructed, or altered sidewalks shall be accessible to and usable by persons with disabilities.

The minimum width of a sidewalk shall be 5 feet on both curb and gutter and flush shoulder roadways. The minimum separation for a 5-foot sidewalk from the back of curb is 2 feet. If the sidewalk is located adjacent to the curb, the minimum width of sidewalk is 6 feet. For sidewalks not adjacent to the curb, at least a 1-foot wide graded area should be provided on both sides, flush with the sidewalk and having a maximum 1:6 slope. Wider sidewalks should be considered in Central Business Districts and in areas where heavy two-way pedestrian traffic is expected.

A 5-foot wide (minimum) sidewalk that connects a transit stop or facility with an existing sidewalk or shared use path shall be included to comply with ADA accessibility standards. ***Chapter 13 – Transit*** provides illustrations of the connection between the sidewalk and transit facility.

Particular attention shall be given to pedestrian accommodations at the termini of each project. If full accommodations cannot be provided due to the limited scope or phasing of a roadway project or an existing sidewalk is not present at the termini, an extension of the sidewalk to the next appropriate pedestrian crossing or access point should be considered. If pedestrian facilities are provided, they shall be connected with facilities (e.g. sidewalks, shared use path, and crosswalks on the adjoining projects.

For new construction and reconstructed roadways, grades on sidewalks or shared use paths shall not exceed 5%, unless accessible ramps and landings are provided. However, in a roadway right of way, the grade of sidewalks or shared use paths is permitted to equal the general grade established for the adjacent street or highway. There should be enough sidewalk or path cross slope to allow for adequate drainage, however the maximum shall be no more than 2% to comply with ADA requirements.

Where existing physical constraints make it impracticable for altered elements, spaces, or facilities to fully comply with the requirements for new construction, compliance is required to the extent practicable within the scope of the project. Existing physical constraints include, but are not limited to, underlying terrain, right-of-way availability, underground structures, adjacent developed facilities, drainage, or the presence of a notable natural or historic feature.

Additional information on designing accessible pedestrian facilities is provided by the United States Access Board at the following web site:

***Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way***

Edge drop-offs should be avoided. When drop-offs cannot be avoided, they should be shielded as discussed in ***Section F, Drop-Off Hazards for Pedestrians***.

For additional information concerning the design of sidewalks, refer to ***Section C.7.d*** of ***Chapter 3 – Geometric Design***.

## B.2 Shared Use Paths

Paths are usually set back from the road and separated by a green area, ditch, swales or trees. Shared use paths are intended for use by both pedestrians and bicyclists and shall be accessible. For additional information concerning the design of shared use paths, refer to ***Chapter 9 – Bicycle Facilities***.

## B.3 Shared Streets

Shared uses of a street for people walking, bicycling and driving are referred to as shared streets. These are usually specially designed spaces such as pedestrian streets which are local urban streets with extremely low vehicle speed.

## B.4 Shoulders

Highway shoulders are not intended for frequent use by pedestrians, but do accommodate occasional pedestrian traffic. Highway shoulders often have cross slopes which exceed 2%; consequently they are not considered or expected to fully meet ADA criteria.

# C MINIMIZING CONFLICTS

The planning and design of new streets and highways shall include provisions that support pedestrian travel and minimize vehicle-pedestrian conflicts. These may include:

- Sidewalks and/or shared use paths parallel to the roadway
- Marked pedestrian crossings
- Raised median or refuge islands
- Pedestrian signal features such as pedestrian signal heads and detectors
- Transit stops and shelters

In some situations it may be possible to eliminate a vehicle-pedestrian conflict through close coordination with the planning of pedestrian facilities and activity outside of the highway right of way. Care should be exercised to ensure the elimination of a given conflict point does not transfer the problem to a different location. Any effort to minimize or eliminate conflict points must consider the mobility needs of the pedestrian. The desired travel path should not be severed and the number of required crossing points and/or walking distances should not be significantly increased. Some crossings should be redesigned rather than eliminated or relocated.

## C.1 General Needs

Minimizing vehicle-pedestrian conflicts can be accomplished by providing adequate horizontal, physical, or vertical (primarily for crossings) separation between the roadway and the pedestrian facility.

## C.2 Horizontal Separation

The development of independent systems for pedestrian and motor vehicular traffic is the preferred method for providing adequate horizontal separation.

### C.2.a General Criteria

New sidewalks should be placed as far from the roadway as practical in the following sequence of desirability:

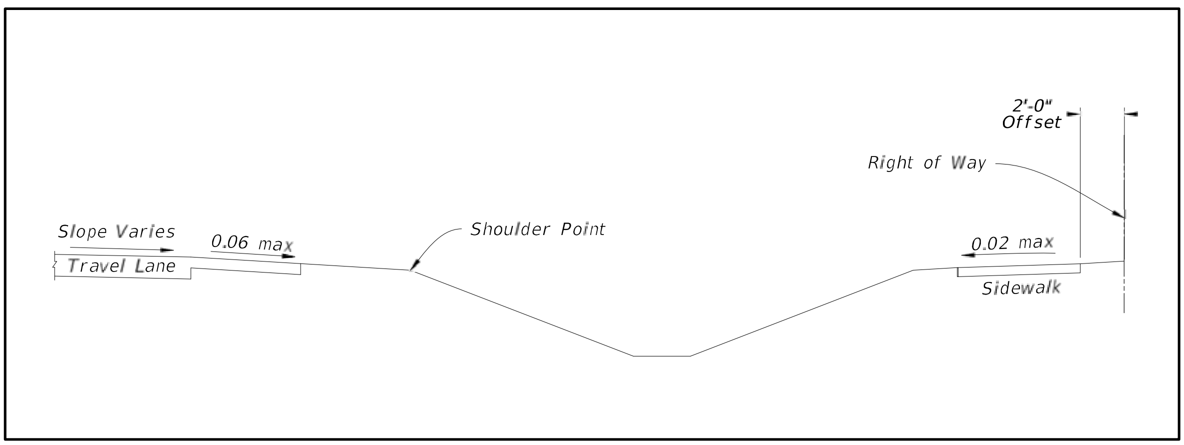
1. As near the right of way line as possible. (ideally, 3 feet of width should be provided behind the sidewalk for above ground utilities)

2. Outside of the clear zone.
3. Sufficiently off-set from the curb to allow for the placement of street trees, signs, utilities, parking meters, benches or other street furniture outside of the sidewalk in urban locations (e.g. town center, business or entertainment district).
4. Five feet from the shoulder point on flush shoulder roadways.
5. At the grass shoulder point of flush shoulder roadways.

Figure 8 – 1 Shoulder Point with Sidewalk provides an illustration of the location of the shoulder point.

On arterial or collector roadways, sidewalks shall not be constructed contiguous to the roadway pavement, unless a curb or other barrier is provided. Nearing intersections, the sidewalk should be transitioned as necessary to provide a more functional crossing location that also meets driver expectation. Further guidance on the placement of stop or yield lines and crosswalks is provided in the ***MUTCD, Part 3**.*

**Figure 8 – 1 Shoulder Point with Sidewalk**




### C.2.b Buffer Widths

Providing a buffer can improve pedestrian safety and enhance the overall walking experience. Buffer width is defined as the space between the sidewalk and the edge of traveled way. On-street parking or bike lanes can also act as an additional buffer. The planting strip or buffer strip should be 6 feet where practical to eliminate the need to narrow or reroute sidewalks around driveways. With this wider buffer strip, the sidewalk is placed far enough back so that the driveway slope does not have to encroach into the sidewalk.Wider sidewalks should be considered in Central Business Districts and in areas where heavy two-way pedestrian traffic is expected.

## C.3 Other Considerations

When designing urban highways, the following measures may be considered to help increase the safe and efficient operation of the highway for pedestrians:

- Use narrower lanes and introduce raised medians to provide pedestrian refuge areas
- Provide pedestrian signal features and detectors
- Prohibit right turn on red
- Control, reduce, or eliminate left and/or right turns
- Prohibit free flow right turn movements
- Prohibit right turn on red
- Reduce the number of lanes
- Use narrower lanes and introduce raised medians to provide pedestrian refuge areas

# D BARRIER SEPARATION

Barriers may be used to assist in the separation of motor vehicular and pedestrian traffic.

## D.1 Longitudinal Barriers

Longitudinal barriers such as guardrails, rigid barriers, and bridge railings are designed primarily to redirect errant vehicles away from roadside hazards. These barriers can also be used to provide valuable protection of pedestrian facilities from out of control vehicles.

Where adequate horizontal separation is not feasible, or where there is a significant hazard from out of control vehicles, longitudinal barriers may be utilized. If electing to use barriers, special consideration should be made to ensure proper sight distance near driveways and intersections is maintained. Figure 8 – 2 Sidewalk with Guardrail illustrates the correct placement of a sidewalk in conjunction with a guardrail.

When a sidewalk or shared use path is within 4 feet of the back of a guardrail with steel posts, a pipe rail should be installed on the back of the post. For a guardrail with timber posts, the bolt ends should be trimmed flush with the post or recessed. See Figure 8 – 3 Guardrail with Pipe Rail Detail for an illustration of when a pipe rail is needed. Additional information on the design of guardrails adjacent to a sidewalk or shared use path can be found in the ***FDOT Design Standards, Index 400.***

## Figure 8 – 2 Sidewalk with Guardrail

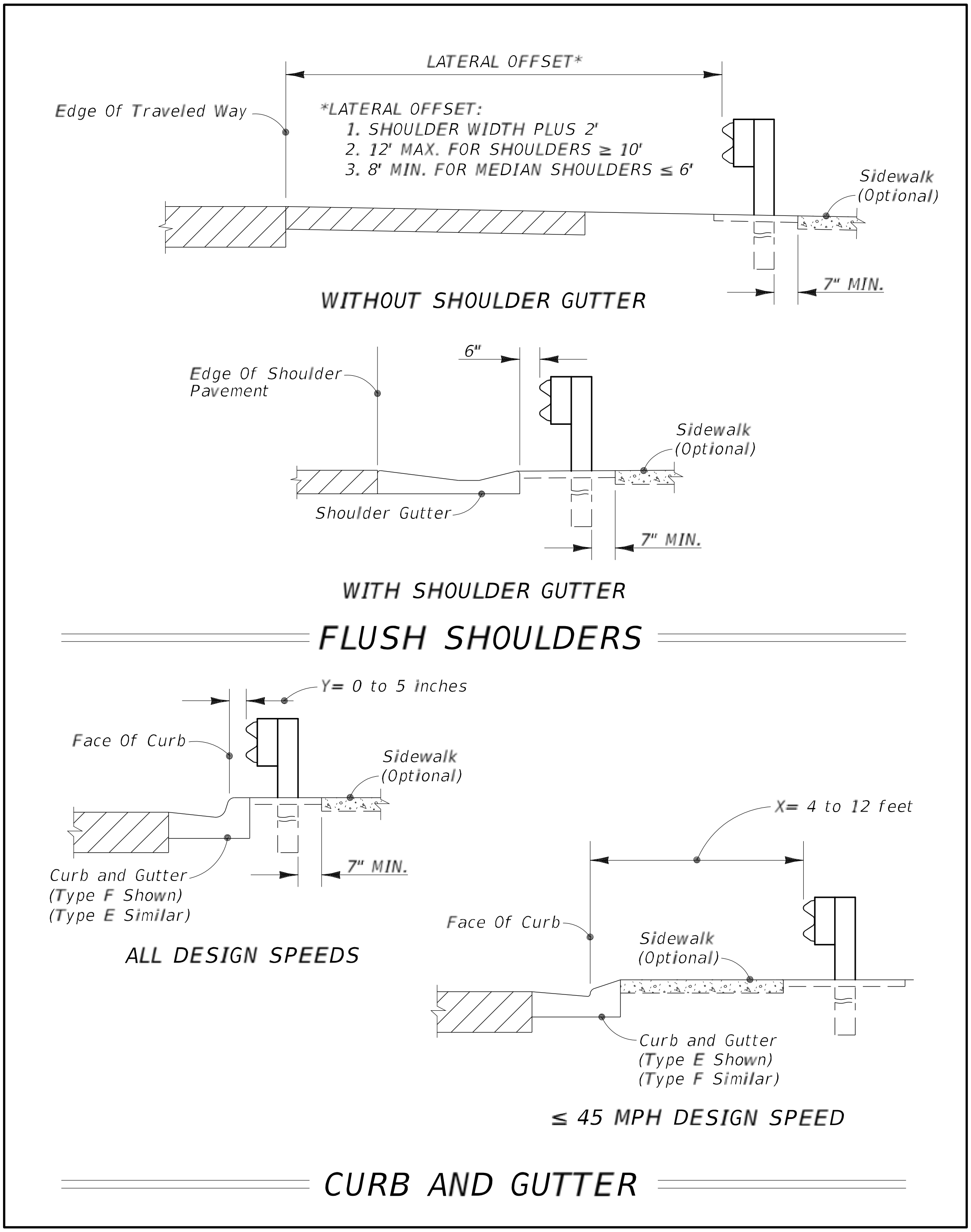
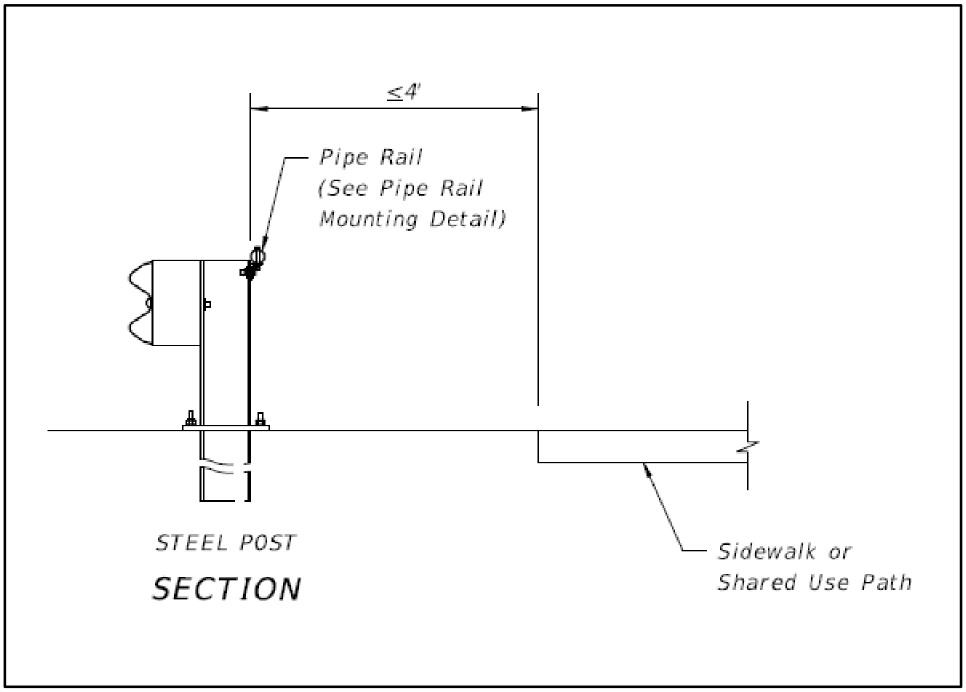


**Figure 8 – 3 Guardrail with Pipe Rail Detail**




## D.2 Fencing, Pedestrian Channelization Devices or Landscaping

Fencing, pedestrian channelization devices or landscaping may be used to discourage pedestrian access to the roadway and aid in channeling pedestrian traffic to the proper crossing points. These should not be considered a substitute for longitudinal barriers, but may be used in conjunction with redirection devices.

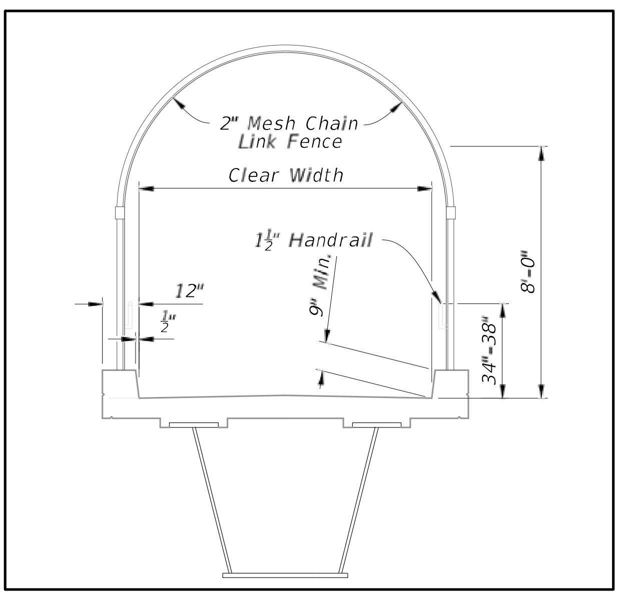
# E GRADE SEPARATION

Grade separation may be selectively utilized to support the crossing of large pedestrian volumes across highways where the traffic volume on the roadway is at or near capacity or where speeds are high. Overpasses or underpasses may be justified at major pedestrian generators such as schools, shopping centers, sports and amusement facilities, transit centers, commercial buildings, parks and playgrounds, hospitals, and parking facilities.

The minimum clear width of any stand-alone pedestrian overpass or underpass on a pedestrian accessible route is 8 feet. However, if the contiguous sidewalk or path is greater than 8 feet wide, the clear width of the overpass or underpass should match that width. The minimum clear height of a pedestrian overpass or underpass is 8 feet. See Figure 8 – 4 for an example of a pedestrian bridge typical section.

The ***FDOT Structures Manual - Volume 1 - Structures Design Guidelines (SDG), Section 10*** provide additional guidance on engineered steel and concrete pedestrian bridges.

**Figure 8 – 4 Pedestrian Bridge Typical Section**




Notes: 1. Pedestrian handrails may be required. See the ***2006 Americans with Disabilities Act Standards for Transportation Facilities***.

2. Other superstructure configurations may be used provided an 8 ft. minimum headroom is maintained.

## E.1 Overpasses

Pedestrian overpasses are typically bridge structures over major roadways or railroads. Overpasses should provide elevator access if they are not designed to provide accessible ramps with compliant slopes, level landings, and handrails on both sides. Bridges over roadways should be covered or screened to reduce the likelihood of objects being dropped or thrown below. The area adjacent to overpasses may be fenced to prevent unsafe crossings and to channel pedestrians to the overpass structure.

## E.2 Underpasses

Pedestrian underpasses or tunnels perform the same function as overpasses. Their use is convenient when the roadway is elevated above the surrounding terrain.

Underpasses should be adequately maintained to reduce potential problems in lighting, cleaning, policing, and flooding and to maximize safety. The area adjacent to underpasses may be fenced to prevent unsafe crossings and to channel pedestrians to the underpass structure.

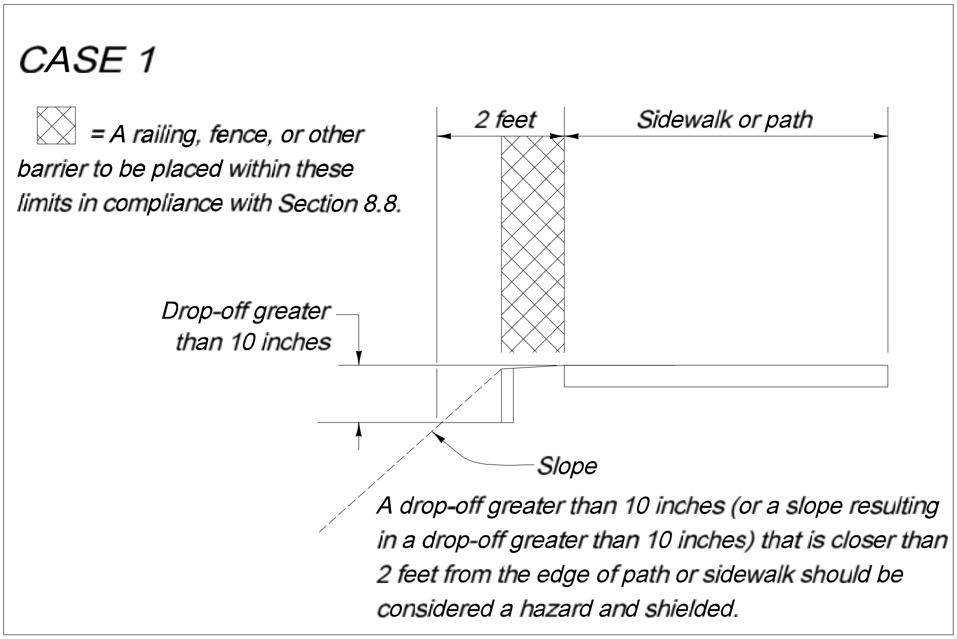
## F DROP-OFF HAZARDS FOR PEDESTRIANS

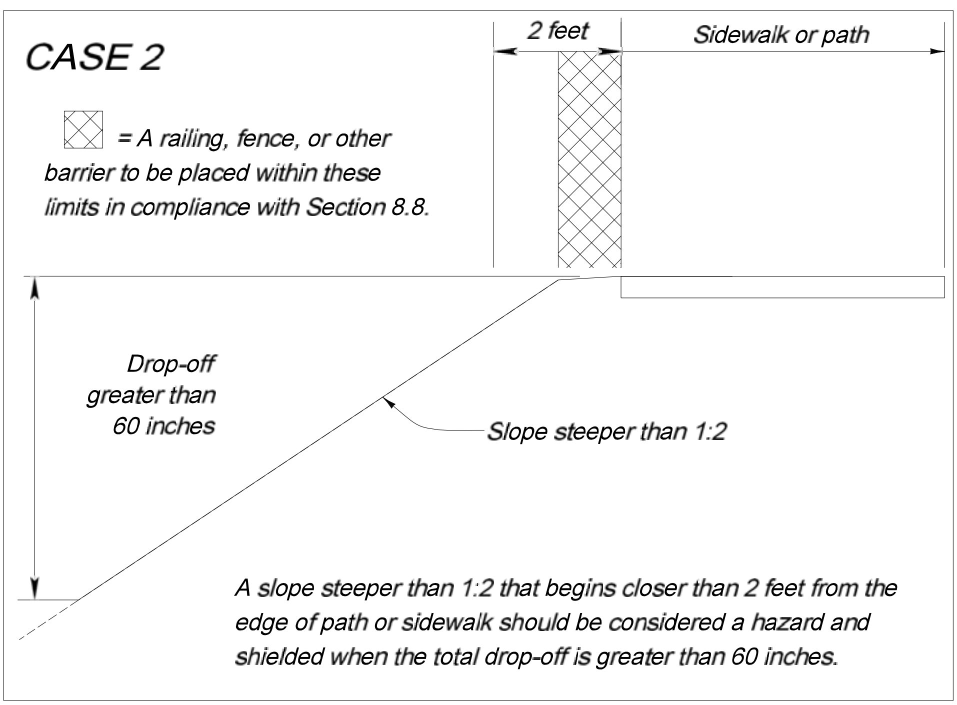
Drop-off hazards are defined as steep or abrupt downward slopes that can be perilous to pedestrians and bicyclists. Consider shielding any drop-off determined to be a hazard. Care should be taken when using Pedestrian/Bicycle Railings or fencing near intersections or driveways as they could obstruct the driver's line of sight. To reduce the need for railings as a sidewalk or shared use path approaches an intersection, consider extending cross drains and side drains to minimize drop-offs.

There are two cases that require shielding as shown in Figure 8 – 5 Drop-Off Hazards for Pedestrians and Bicyclists. Depending on the depth of the drop-off and severity of the conditions below, shielding may be necessary for cases other than described above.

Railings or fences should be provided for vertical drop-off hazards or where shielding is required. The standard height for a pedestrian/bicycle railing is 42 inches. A 48 inch tall pedestrian/bicycle railing should be used when sidewalk grades are steeper than 5% and bicycle travel is expected. A standard railing is generally intended for urbanized areas, locations attaching to bridge rail or along concrete walkways. Fencing is generally intended for use in rural areas along paths and trails.

## Figure 8 – 5 Drop-Off Hazards for Pedestrians and Bicyclists



# G PEDESTRIAN CROSSINGS

The design of pedestrian crossings and parallel pathways within the right of way shall be considered an integral part of the overall design of a street or highway.

The development of protection at any remaining crossings or conflict points must be adequate to achieve a total pedestrian transportation mode that is reasonably safe.

## G.1 Crosswalks

The design of pedestrian crosswalks should be based on the following requirements:

- Crosswalks should be placed at locations with sufficient sight distances
- At crossings, the roadway should be free from changes in alignment or cross section
- The entire length of crosswalk shall be visible to drivers at a sufficient distance to allow a stopping maneuver
- Stop bars or yield markings, in conjunction with the appropriate signing, shall be provided at all marked crosswalks
- Crosswalks shall be easily identified and clearly delineated, in accordance with the ***Manual on Uniform Traffic Control Devices (MUTCD)*** ***and*** ***Rule 14-15.010, F. A. C.***

### G.1.a Marked Crosswalks

Marked crosswalks are one tool to allow pedestrians to cross the roadway safely. They are often used in combination with other treatments (signs, flashing beacons, curb extensions, pedestrian signals, raised median or refuge islands, and enhanced overhead lighting). Marked crosswalks serve two purposes: 1) to inform motorists of the location of a pedestrian crossing so that they have time to lawfully yield to or stop for a crossing pedestrian; and 2) to assure the pedestrian that a legal crosswalk exists at a particular location. See Figure 8 – 6 Pedestrian Median Refuge with Curb Extensions for an example of a pedestrian median refuge with a curb extension.

**Figure 8 – 6 Pedestrian Median Refuge with Curb Extension**

Urban Street Design Guide, National Association of City Transportation Officials (NACTO)

Marked crosswalks on an uncontrolled leg of an intersection or a mid-block location shall be supplemented with other treatments (such as signing, beacons, curb extensions, raised medians, raised traffic islands, or enhanced overhead lighting) when any of the following conditions exist:

1. Where posted speeds are greater than 40 mph.
2. On a roadway with 4 or more lanes without a raised median or raised traffic island that has an ADT of 12,000 or greater.
3. On a roadway with 4 or more lanes with a raised median or raised traffic island that has or is projected to have (within 5 years) an ADT of 15,000 or greater.

See ***Chapter 6 – Lighting*** for information on illuminating crosswalks and pedestrian facilities.

Additional guidance on marked crosswalks can be found in the ***AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*** and ***FHWA's Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines.***

Marked crosswalks can also be used to create midblock crossings.

### G.1.b Midblock Crosswalks

Midblock crosswalks facilitate crossings to places that people want to go but that are not well served by the existing sidewalk or path network. These pedestrian crossings commonly occur at schools, parks, museums, waterfronts, and other destinations. Designers should study both existing and projected pedestrian volumes in assessing warrants for midblock crossings to account for latent demand.

Midblock crossings are located according to a number of factors including pedestrian volume, traffic volume, roadway width, traffic speed and type, desired paths for pedestrians, land use, and to accommodate transit connectivity. Midblock crossings should not be installed where sight distance or sight lines are limited for either the motorist or pedestrian.

Midblock crossings should be marked and signed in accordance with the ***MUTCD***. See Figure 8 – 7 Raised Midblock Crosswalks for an example of a midblock crosswalk.

**Figure 8 – 7 Raised Midblock Crosswalk**

Suwannee Street, Tallahassee, Florida

Crosswalks may be supplemented with Pedestrian Hybrid Beacons (PHB) or Rectangular Rapid Flashing Beacons (RRFBs). Illumination should be evaluated if night-time pedestrian activity is expected. See ***Chapter 6 – Lighting*** for further information.

A PHB is a special type of beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk. ***Chapter 4F. Pedestrian Hybrid Beacons, MUTCD*** provides additional information regarding their installation. See Figure 8 – 8 Pedestrian Hybrid Beacon for an example of a pedestrian hybrid beacon.

http://mutcd.fhwa.dot.gov/kno_2009r1r2.htm

**Figure 8 – 8 Pedestrian Hybrid Beacon (PHB)**

16th Street South, St. Petersburg, Florida

The RRFB uses rectangular-shaped high-intensity LED-based indications, flashes rapidly in a wig-wag "flickering" flash pattern, and is mounted immediately between the crossing sign and the sign's supplemental arrow plaque. Use of PHBs should be limited to locations with the most critical safety concerns, such as pedestrian and school crosswalks across uncontrolled approaches. The ***MUTCD*** provides further information on obtaining ***interim approval*** for the use of RRFBs. See Figure 8 – 9 Pedestrian Median Refuge with Rectangular Rapid Flashing Beacon for an example of a Rectangular Rapid Flashing Beacon (RRFB).

http://mutcd.fhwa.dot.gov/res-interim_approvals.htm

**Figure 8 – 9 Pedestrian Median Refuge with Rectangular Rapid Flashing Beacons**


4th Street North, St. Petersburg, Florida

## G.2 Curb Ramps

Curb ramps provide access between the sidewalk and the street for people who use mobility aids such as wheelchairs or scooters, people pushing strollers and pulling suitcases, people on bicycles, and delivery services. Curb ramps and at grade connections from the sidewalk to the roadway shall include detectable warnings. Curb ramps shall be provided at all pedestrian crossings, including mid-block crossings and intersections to give persons with disabilities safe access. A level landing is necessary for turning, maneuvering, or bypassing the sloped surface

## G.3 Controls

Signs, signals, and markings should be utilized to provide the necessary information and direction for pedestrians. All directions and regulations should be clear, consistent and logical, and should, at a minimum, conform to the requirements given in the ***MUTCD***. The use of accessible pedestrian signals that include audible and/or vibro-tactile, and visual signals should be considered for pedestrian traffic control and regulation.

## G.4 Sight Distance

The general requirements for sight distances for the driver are given in ***Chapter 3 – Geometric Design***.

Stopping sight distances greater than the minimum should be provided at all pedestrian crossings. These sight distances should include a clear view of the pedestrian approach pathway for at least 15 feet from the outside travel lane. Where parallel pedestrian pathways are within the roadside recovery area, or where casual pedestrian crossings are likely, the normal required stopping sight distance should also include a clear view of the entire roadside recovery area.

Sight distances shall be based upon a driver's eye and object height as discussed in ***Chapter 3 – Geometric Design***. Due to the small size of some pedestrians (particularly children), they are generally easy to confuse with other background objects.

Parking shall be prohibited where it would interfere with the required sight distance. Particular care should be exercised to ensure ample mutual sight distances are provided at all intersections and driveways.

## G.5 Rail Crossings

Roadways, sidewalks and shared use paths at grade may cross light rail, surface commuter rail, conventional passenger rail, and freight railroads. Special design considerations are needed for these pedestrian intersections so that pedestrians are warned of the crossing and potential presence of a train. In addition, these crossings have specific accessibility requirements relating to surface continuity which must be met. See ***Chapter 7 – Rail-Highway Crossings*** for further information. The ***Federal Railroad Administration*** may impose additional requirements for the design and construction of rail crossings.

## H LIGHTING

Lighting of the roadway itself is not only important for the safety of vehicular traffic, but also valuable for the protection of pedestrians. Vehicle headlamps often do not provide sufficient lighting to achieve the required stopping sight distance. Since this requirement is of vital importance at any potential pedestrian crossing point, lighting of the crossing should be considered. Lighting a street or highway is also valuable in improving the pedestrian's view of oncoming vehicles. At intersections or other locations with vehicle turning maneuvers, vehicle headlights may not be readily visible to the pedestrian.

Lighting shall be provided in pedestrian underpasses and should be considered on pedestrian overpasses. All pedestrian lighting shall be vandal resistant. The installation of daytime lighting is warranted when underpass user visibility requirements are not met with sunlight. Pedestrian underpass and overpass lighting should conform to the general lighting requirements given in the American Association of State Highway and Transportation Officials (AASHTO) Roadway Lighting Design Guide.

The general requirements for lighting on streets and highways are given in ***Chapter 6 – Lighting***. Pathways adjacent to a street or highway should not be illuminated to a level more than twice that of the roadway itself.

In general, lighting should be considered as warranted when it is necessary, at night, to provide the mutual sight distance capabilities described in the preceding ***Chapter 3 – Geometric Design***. Locations with significant night time pedestrian traffic that should be considered for lighting of the roadway and adjacent pedestrian facilities include the following:

- Any street or highway that meets the warranting criteria given in ***Chapter 6 –***
- ***Lighting***
- Streets and highways with speed limits in excess of 40 mph that do not have adequate pedestrian conflict elimination
- Sections of highway with minimal separation of parallel pedestrian pathways
- Intersections, access and decision points, and areas adjacent to changes in alignment or cross sections
- Areas adjacent to pedestrian generators
- Transit stops and other mass transit transfer locations
- Parking facilities

- Entertainment districts, sports/recreation complexes, schools, and other activity centers generating night travel
- Pedestrian crossings
- Any location where improvement of night time sight distance will reduce the hazard of vehicle-pedestrian conflicts

See ***Chapter 6 – Lighting*** for further information on lighting of pedestrian facilities and shared use paths.

# I REFERENCES FOR INFORMATIONAL PURPOSES

- Florida Department of Transportation Transit Facility Design
  http://www.dot.state.fl.us/transit/Pages/NewTransitFacilitiesDesign.shtm

- USDOT/FHWA ADA Standards for Accessible Design (ADAAG)
  http://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/ada-standards

- 2006 Americans with Disabilities Act Standards for Transportation Facilities
  https://www.access-board.gov/guidelines-and-standards/transportation/facilities/ada-standards-for-transportation-facilities

- 2012 Florida Accessibility Code for Building Construction
  https://www.flrules.org/gateway/ruleno.asp?id=61G20-4.002

- AASHTO – Guide for the Planning, Design, and Operation of Pedestrian Facilities
  https://bookstore.transportation.org/

- AASHTO – Roadway Lighting Design Guide I
  https://bookstore.transportation.org/

- NACTO Urban Streets Design Guide
  http://nacto.org/usdg

- Designing Walkable Urban Thoroughfares (CNU and ITE)
  http://www.cnu.org/streets

- Project Management Handbook (CSS)
  http://www.dot.state.fl.us/projectmanagementoffice/Publications/default.shtm

- FHWA Policy Memo for Flexibility in Pedestrian and Bicycle Facility Design
  http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/design_guidance/design_flexibility.cfm

- AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications, 7th Edition, (2014) with Interim Revisions (2015 and 2016)
  https://bookstore.transportation.org/Home.aspx

- Federal Railroad Administration General Manual - Policies, Procedures, and General Technical Bulletins (July 2014)
  http://www.fra.dot.gov/Elib/Details/L16208

# CHAPTER 9

# BICYCLE FACILITIES

# TABLES



# FIGURES

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# CHAPTER 9

# BICYCLE FACILITIES

## A INTRODUCTION

Bicycle facilities should be given full consideration in the planning and development of transportation facilities, including the incorporation of such facilities into state, regional, and local transportation plans and programs under the assumption that transportation facilities will be used by cyclists. Bicycle facilities should be established in conjunction with the construction, reconstruction, or other change of any transportation facility and special emphasis should be given to projects in or within 1 mile of an urban area. The provision for bicycle facilities is also desirable for resurfacing, restoration & rehabilitation (RRR) projects.

Bicycle and pedestrian facilities are not required to be established:

1. Where their establishment would be contrary to public safety;
2. When the cost would be excessively disproportionate to the need or probable use; or
3. Where other available means or factors indicate an absence of need.

Appropriately designed and located bicycle facilities play an important role in supporting bicycle travel. Bicyclists should be considered in all phases of transportation planning, design, construction and maintenance activities. Particular emphasis should be given to new construction, reconstruction, intersection improvement, and transit projects. Bicycle facilities can include bicycle lanes, paved shoulders, wide curb lanes, shared lanes, shared use paths, and bicycle parking facilities.

In addition to the design criteria provided in this chapter, the ***2006 Americans with Disabilities Act Standards for Transportation Facilities*** as required by ***49 C.F.R 37.41*** or ***37.43*** and the ***2012 Florida Accessibility Code for Building Construction*** as required by ***61G20-4.002*** impose additional requirements for the design and construction of facilities such as shared use paths and structures that include provisions for pedestrians.

# B ON-STREET FACILITIES

Provisions for bicycle traffic should be incorporated in the original roadway design. All roadways, except where bicycle use is prohibited by law, should be designed, constructed and maintained under the assumption they will be used by bicyclists. Roadway conditions should be favorable for bicycling, with smooth pavement and limited changes in elevation along edge lines. Drainage inlets and utility covers that cannot be moved out of the travel way should be designed flush with grade, well seated, and make use of bicycle-compatible grates and covers.

Railroad grade crossings on a diagonal can cause steering difficulties for bicyclists. Crossings for bicycle facilities should be perpendicular to the rail. This can be accomplished with a widened shoulder or bicycle lane, or separate path. Consideration should be given to improving the smoothness of the crossing and reducing the width and depth of the flangeway opening. Flangeway fillers can be used on heavy rail lines to minimize the size of the opening adjacent to the rail.

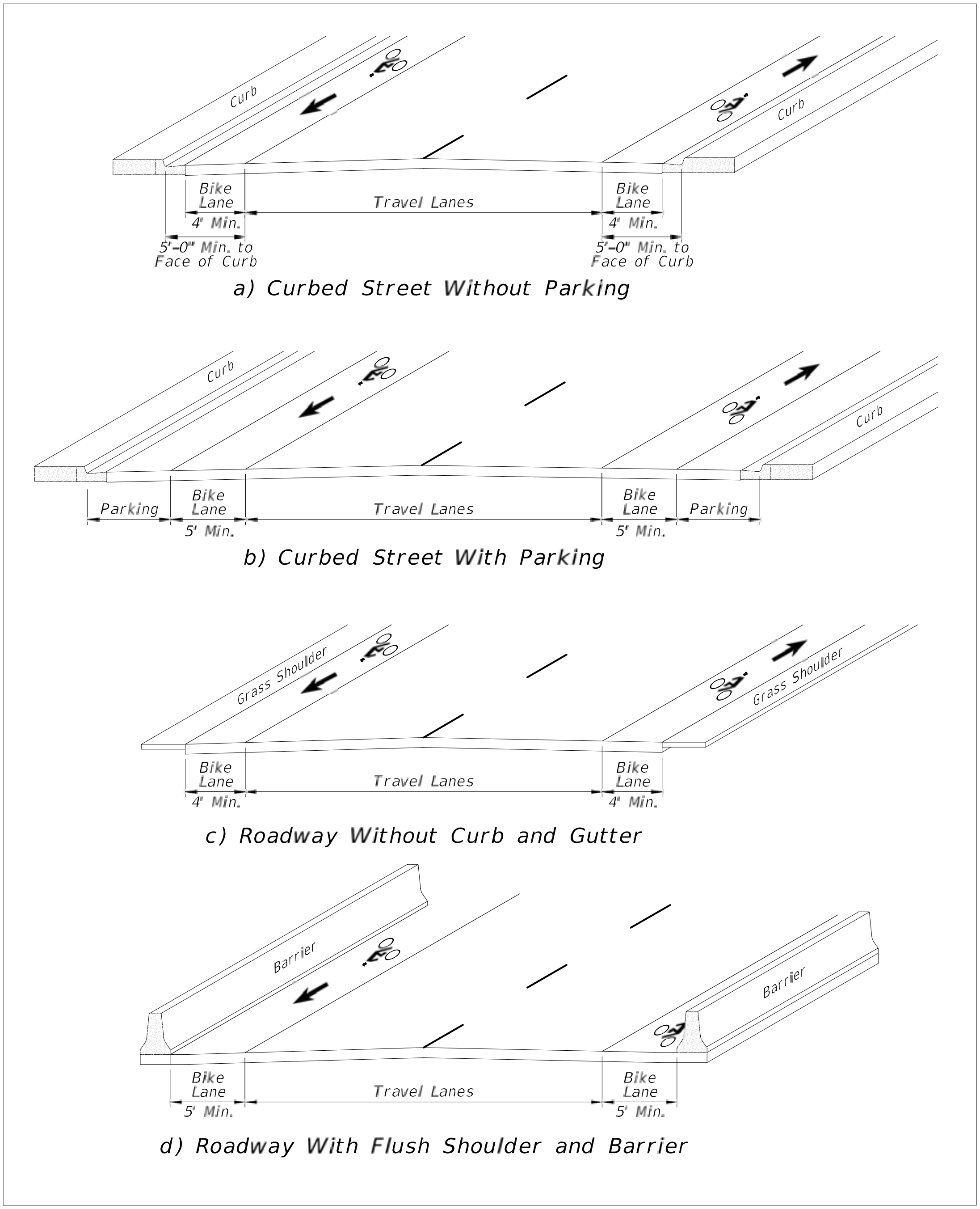
Bicycle lanes, paved shoulders, wide curb lanes, or shared lanes should be included to the fullest extent feasible. The appropriate selection of a bicycle facility depends on many factors, including motor vehicle and bicycle traffic characteristics, adjacent land use and expected growth patterns. All new or reconstructed arterial and collector roadways, in and within one mile of an urban area, should include bicycle lanes.

Rumble strips used in a traffic lane to alert operators to conditions ahead (e.g. stop signs, traffic signals or curves) should provide clear space (free of rumble strips) for bicyclists. This clear space may be a paved shoulder or if no paved shoulder is present, a minimum of 1.5 feet of clear space at the outermost portion of the lane.

## B.1 Bicycle Lanes

Bicycle lanes delineate available roadway space for preferential use by bicyclists; providing more predictable movements by motorists and bicyclists. Bicycle lanes also help increase the total capacity of highways carrying mixed bicycle and motor vehicle traffic. Bicycle lanes shall have a minimum functional width of 4 feet. At least 1 foot additional width is needed when the bicycle lane is adjacent to a curb or other barrier, on-street parking is present, there is substantial truck traffic (>10%), or posted speeds exceed 50 mph. Minimum bicycle lane widths are illustrated in Figure 9 – 1 Minimum Widths for Bicycle Lanes. The 4-foot bicycle lane shown in the flush shoulder typical section assumes the grass portion of the shoulder provides emergency maneuvering room.

## Figure 9 – 1 Minimum Widths for Bicycle Lanes



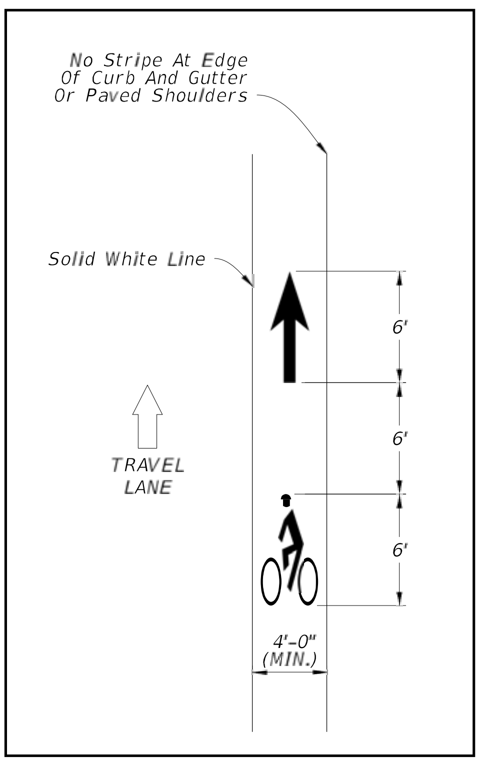
Bicycle lanes are one-way facilities and carry bicycle traffic in the same direction as the adjacent motor vehicle traffic. A bicycle lane should be delineated from the travel lanes with a solid white line and be marked with the bicycle symbol and arrow as shown in Figure 9 – 2 Detail of Bicycle Lane Markings. The dimensions for each pavement marking is 72” long, separated by 72”.

The recommended placement of bicycle lane markings is:

a) At the beginning of a bicycle lane, on the far side of major intersections, and prior to and within the bicycle lane between a through lane and turn lane.

b) Along the roadway as needed to provide a maximum spacing of 1,320 for posted speeds less than or equal to 45 mph, 2,640 feet for a posted speed of 50 mph or greater.

**Figure 9 – 2 Detail of Bicycle Lane Markings**



If used, bike lane signs and plaques should be placed in advance of the upstream end of the bicycle lane, at the downstream end of the bicycle lane, and at periodic intervals based upon prevailing speed of bicycle and other traffic, block length, and distances from adjacent intersections, and other considerations. They should only be used in conjunction with marked bicycle lanes. Bike lane signs are not required.

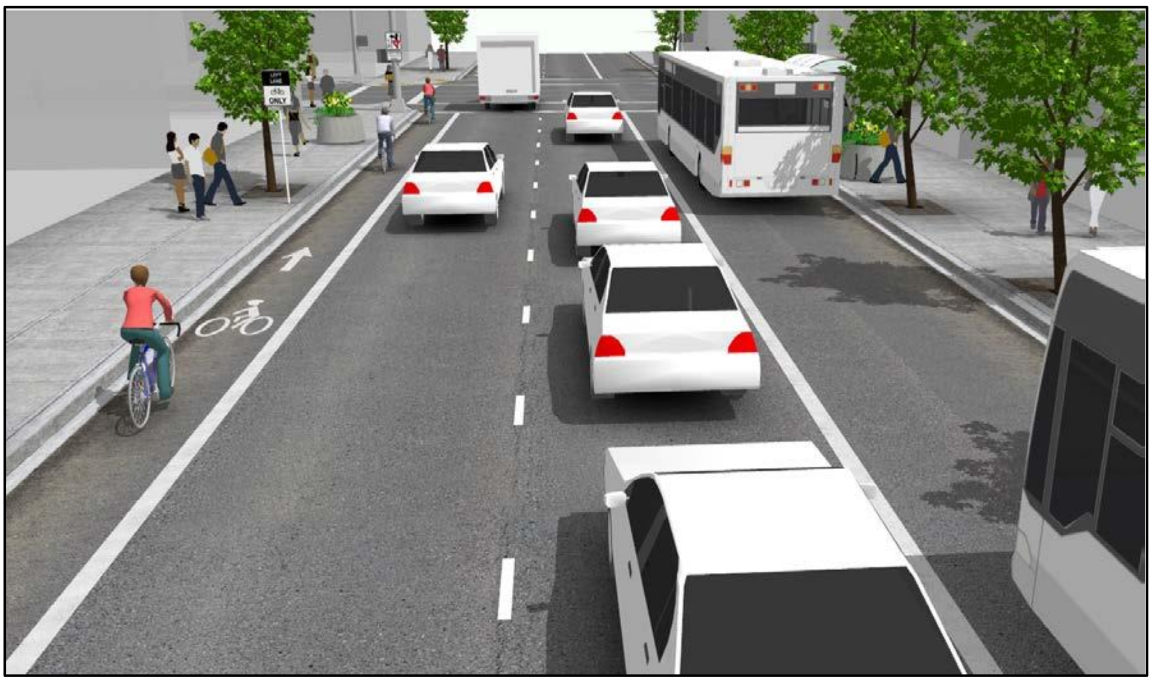
**Figure 9 – 3 Bicycle Lanes**


NACTO Urban Bikeway Design Guide, National Association of City Transportation Officials

A through bicycle lane shall not be positioned to the right of a right turn only lane or to the left of a left turn only lane. For new construction, reconstruction, and traffic operations projects, where bicycle lanes are provided between the through lane and right turn lane, bus bay or parking lane they shall be a minimum of 5 feet wide. For bicycle lanes adjacent to parking lanes, if the parking volume is substantial or the turnover is high a width of 6 - 7 feet is desirable to avoid opening vehicle doors.

On one-way streets, bicycle lanes should generally be placed on the right side of the street. A bicycle lane on the left side of the street can be considered when a bicycle lane on the left will substantially decrease the number of conflicts, such as those caused by frequent bus traffic, heavy right turning movements, high-turnover parking lanes, or if there are a significant number of left turning bicyclists. See Figure 9 – 4 Left Side Bicycle Lanes for an illustration.

**Figure 9 – 4 Left Side Bicycle Lanes**



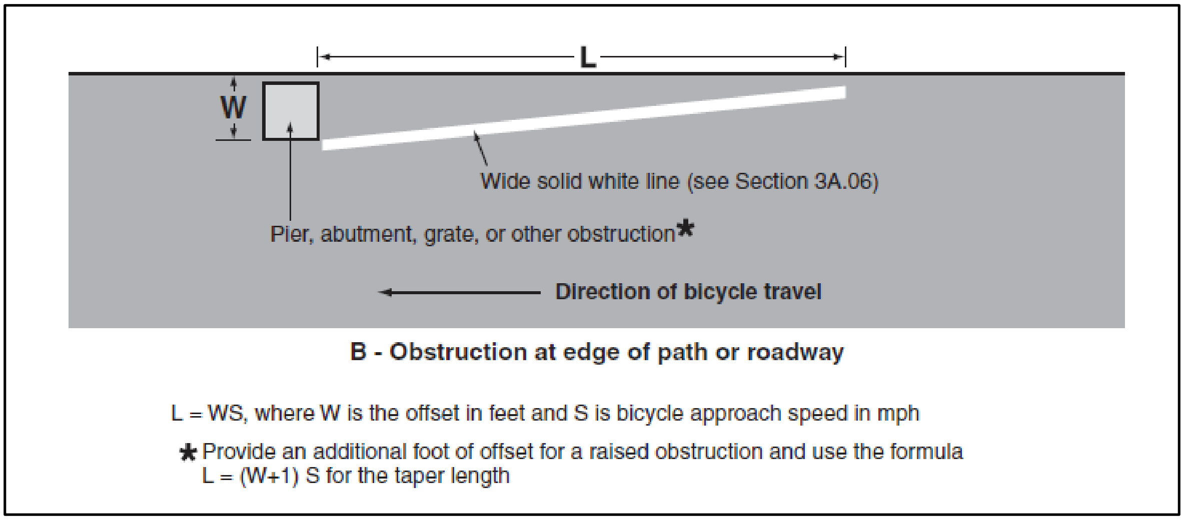
NACTO Urban Bikeway Design Guide, National Association of City Transportation Officials

Bicycle lanes shall not be provided on the circular roadway of a roundabout, and shall be transitioned prior to the roundabout in accordance with the MUTCD.

Existing drainage inlets, grates and utility covers shall be evaluated as to whether they present an obstruction to bicyclists, and should be relocated out of the cyclist's path of travel. Drainage inlets, grates and utility covers to remain should be adjusted to be flush with the adjacent pavement surface, utilize a grate recommended for bicycle travel, and may be marked as an obstruction.

Advance warning of an inlet or other obstruction may be provided as shown in the ***MUTCD, Part 9***. Additional information on appropriate drainage inlets in or near pedestrian and bicycle facilities can be found in the ***Florida Dept. of Transportation's Drainage Manual, Section 3.7.4 Inlet Placement, January 2017 Edition.***

**Figure 9 – 5 Example of Obstruction Pavement Markings**




Traffic signals should be responsive to bicyclists. Regular maintenance of bicycle lanes should be a priority, since bicyclists are unable to use a lane with potholes, debris or broken glass.

In conjunction with resurfacing projects, the roadway width shall be redistributed when practical to provide for bicycle facilities. The types of bicycle facilities considered for implementation include buffered bicycle lanes, bicycle lanes, wide outside lanes, and shared lanes. Lane widths on urban multilane roadways and two-lane curb and gutter roadways may be reduced as shown in Table 9 – 1 Lane Widths to provide for bicycle facilities.

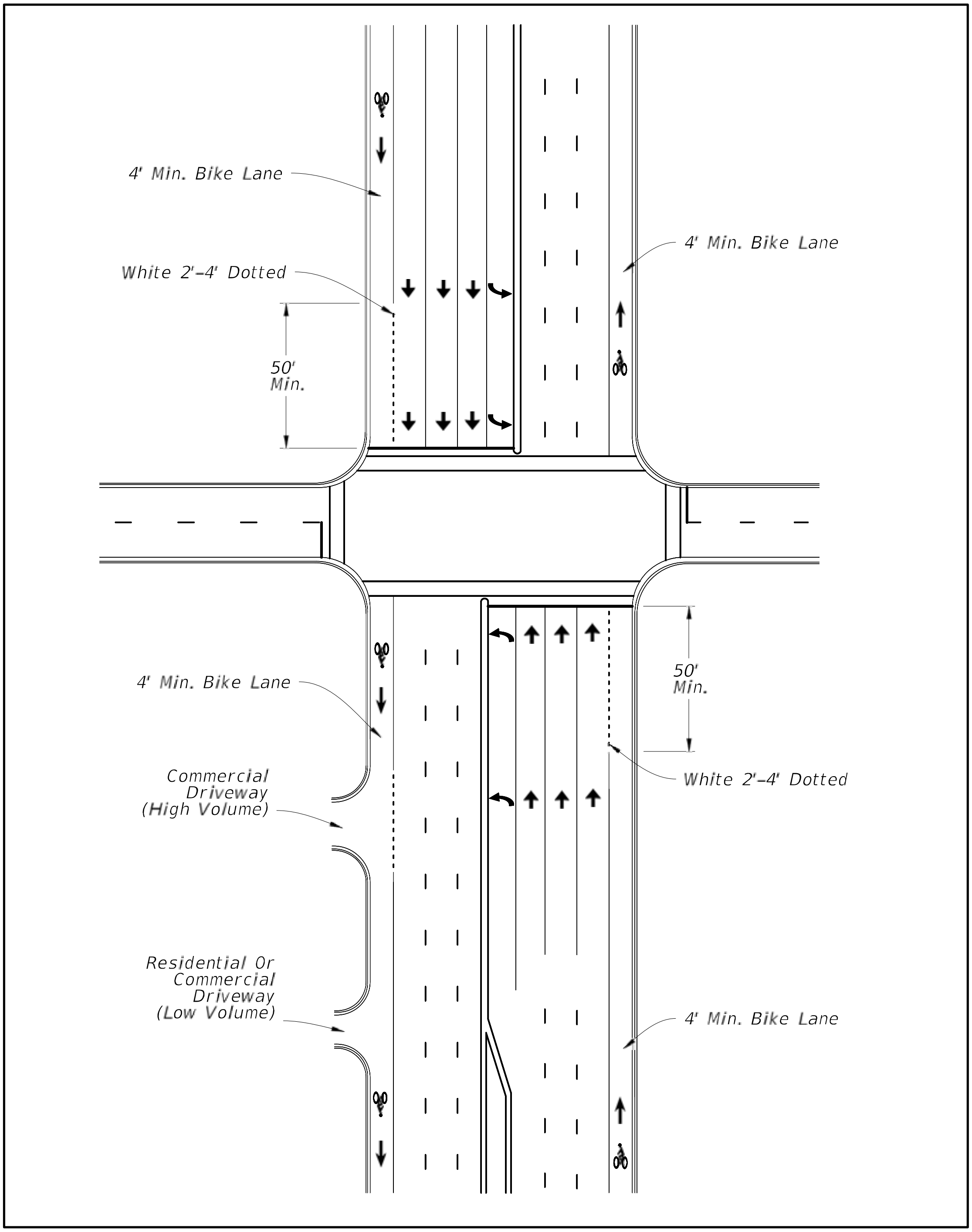
**Table 9 – 1 Lane Widths**
**Urban Multilane or Two-Lane with Curb and Gutter**

| Design Year AADT | Design Speed (mph) | Minimum Thru Lane (ft.) | Minimum Turn Lane (ft.) | Minimum Parking Lane (ft.) |
|---|---|---|---|---|
| ALL | ALL | 10 [1] | 9 [2] | 7 [3] |

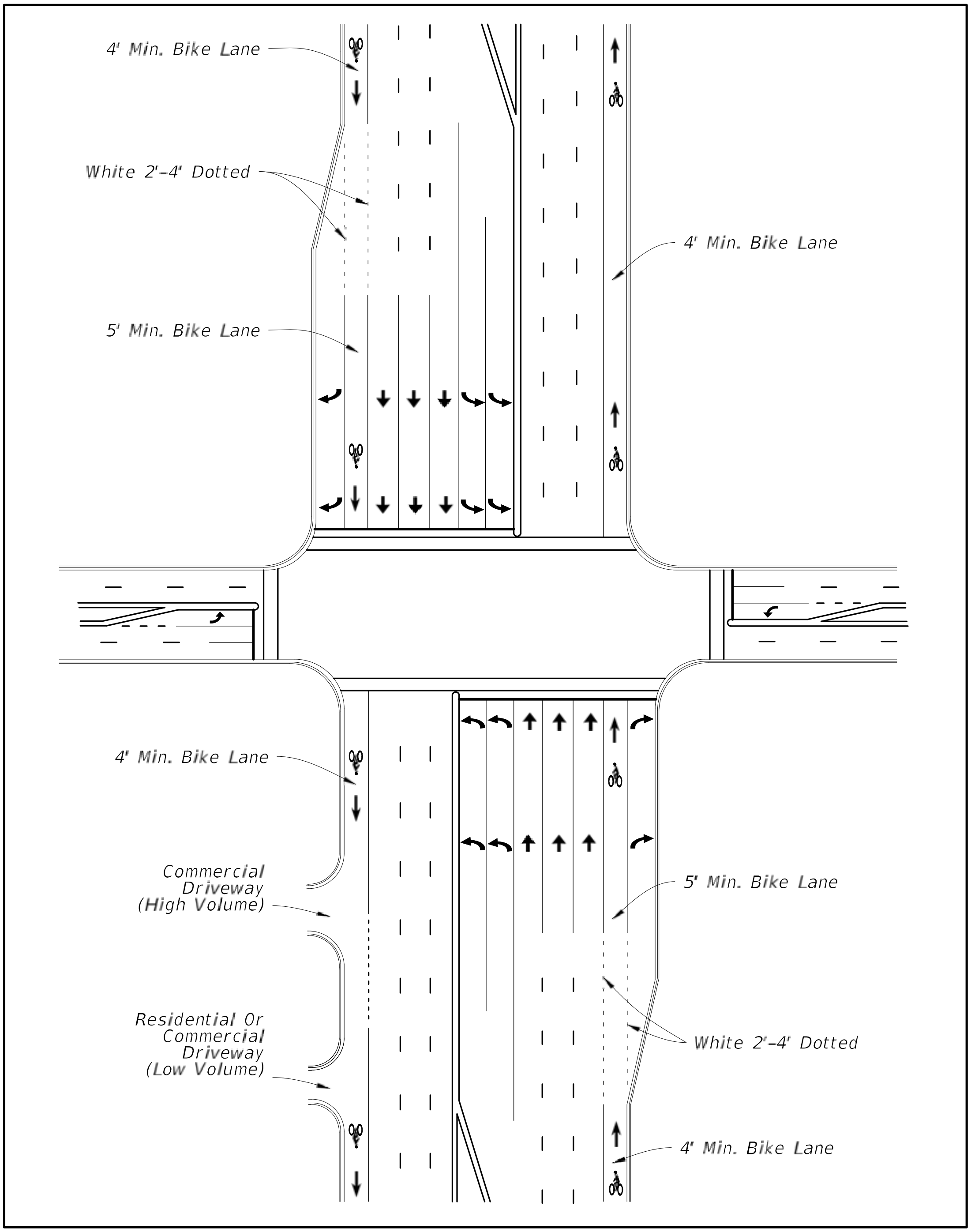
1. 11 ft. where either of the following conditions exist:
   a) Trucks are >10% of Design Year Traffic.
   b) Design Speed is 40 mph or greater.
2. 10 ft. for 2 Way Left Turn Lanes.
3. A minimum width of 7 ft. measured from face of curb may be left in place. Otherwise provide 8 ft. minimum, measured from face of curb.

Various configurations of bicycle lanes on curb and gutter and flush shoulder typical sections are illustrated in Figures 9 – 6 to 9 – 23.

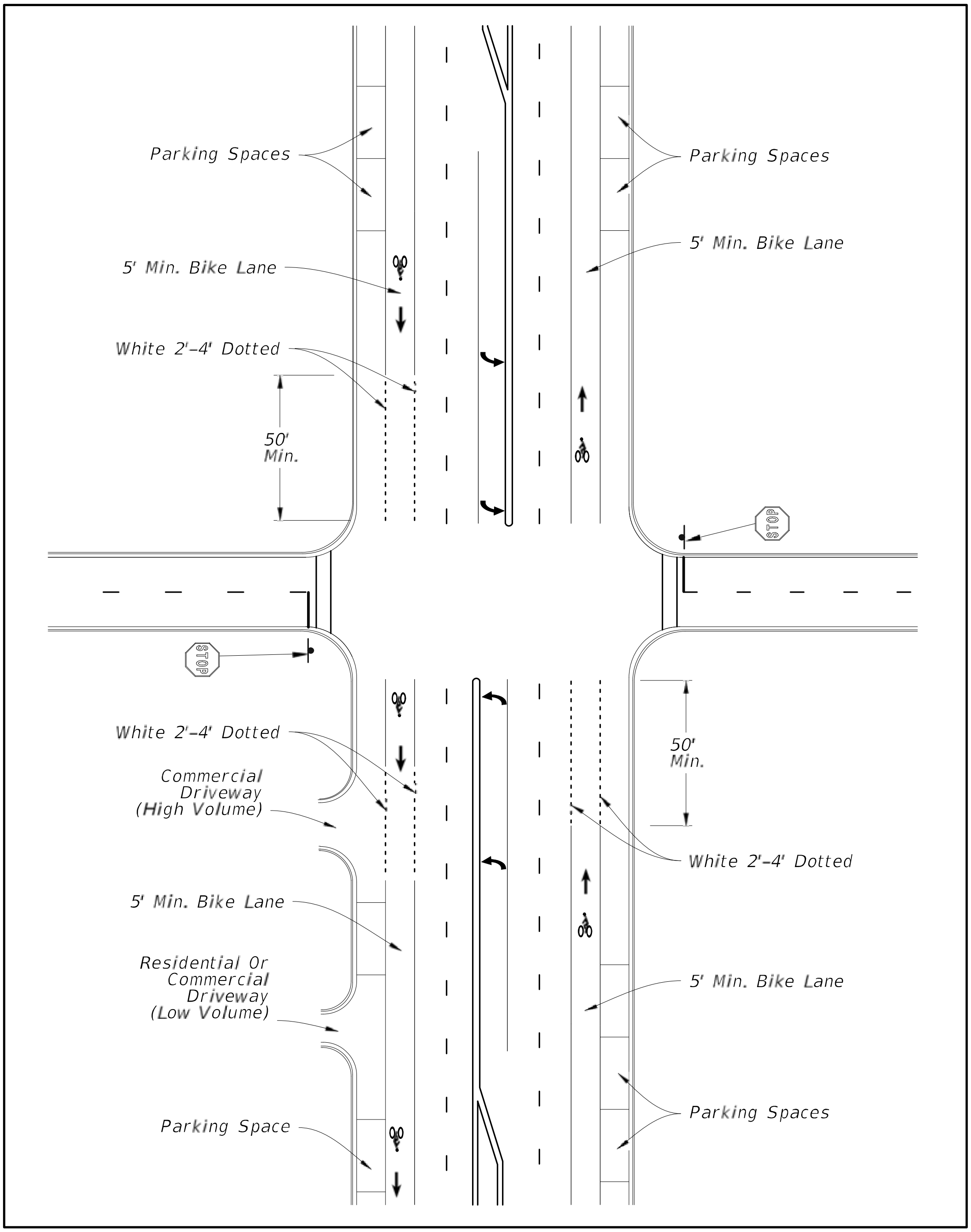
## Figure 9 – 6 Bicycle Lane Markings



## Figure 9 – 7 Bicycle Lanes with Separate Right Turn Lane (Curb and Gutter)



## Figure 9 – 8 Bicycle Lanes with On Street Parking, No Right Turn Lane (Curb and Gutter)



## Figure 9 – 9 Bicycle Lane with Right Turn Drop Lane (Curb and Gutter)

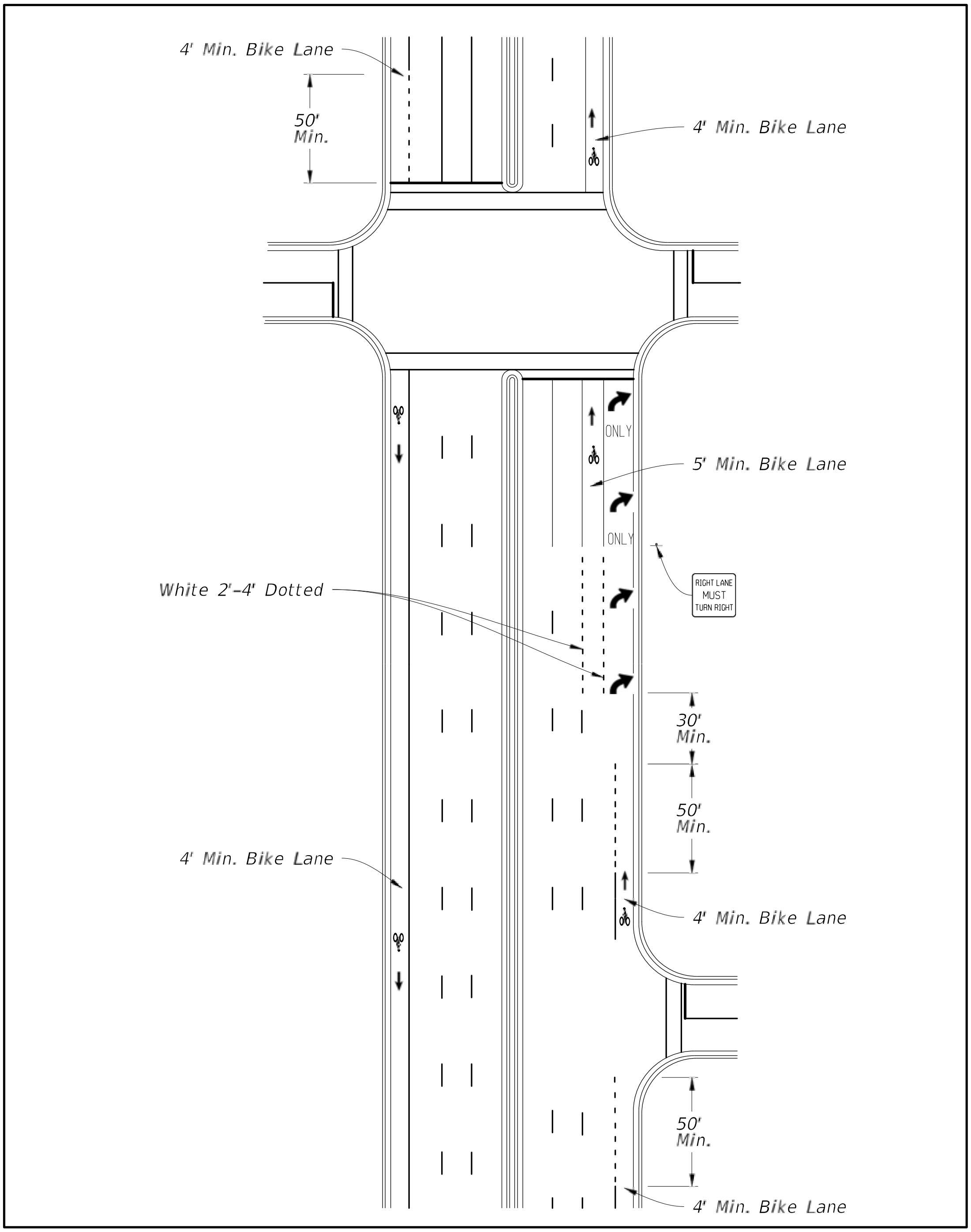


**Figure 9 – 10 "Tee" Intersection with Bicycle Lane, Separate Right and Left Turn Lanes (Curb and Gutter)**

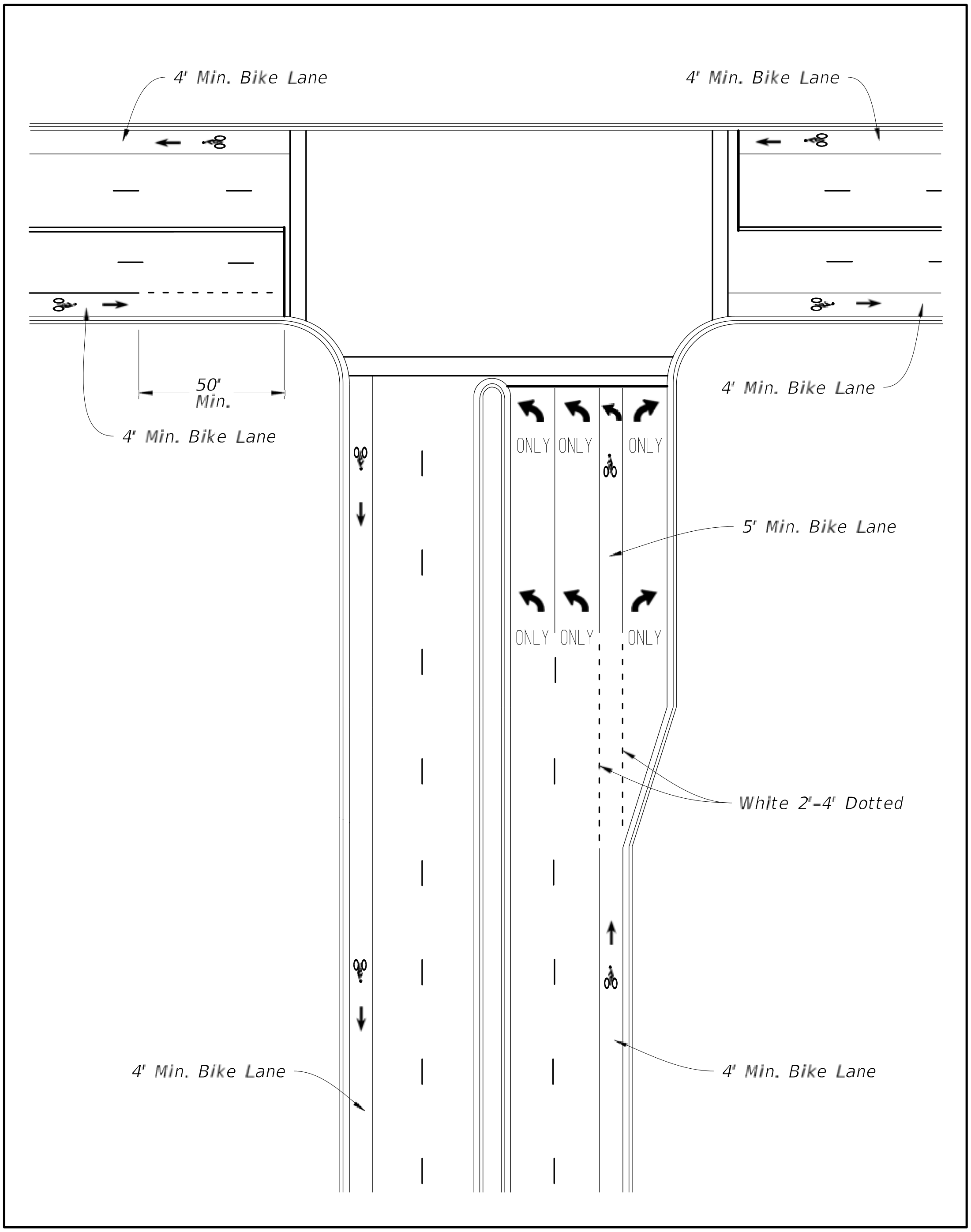


**Figure 9 – 11 "Tee" Intersection with Bicycle Lanes, Left Turn Lane and Right Turn Drop Lane (Curb and Gutter)**

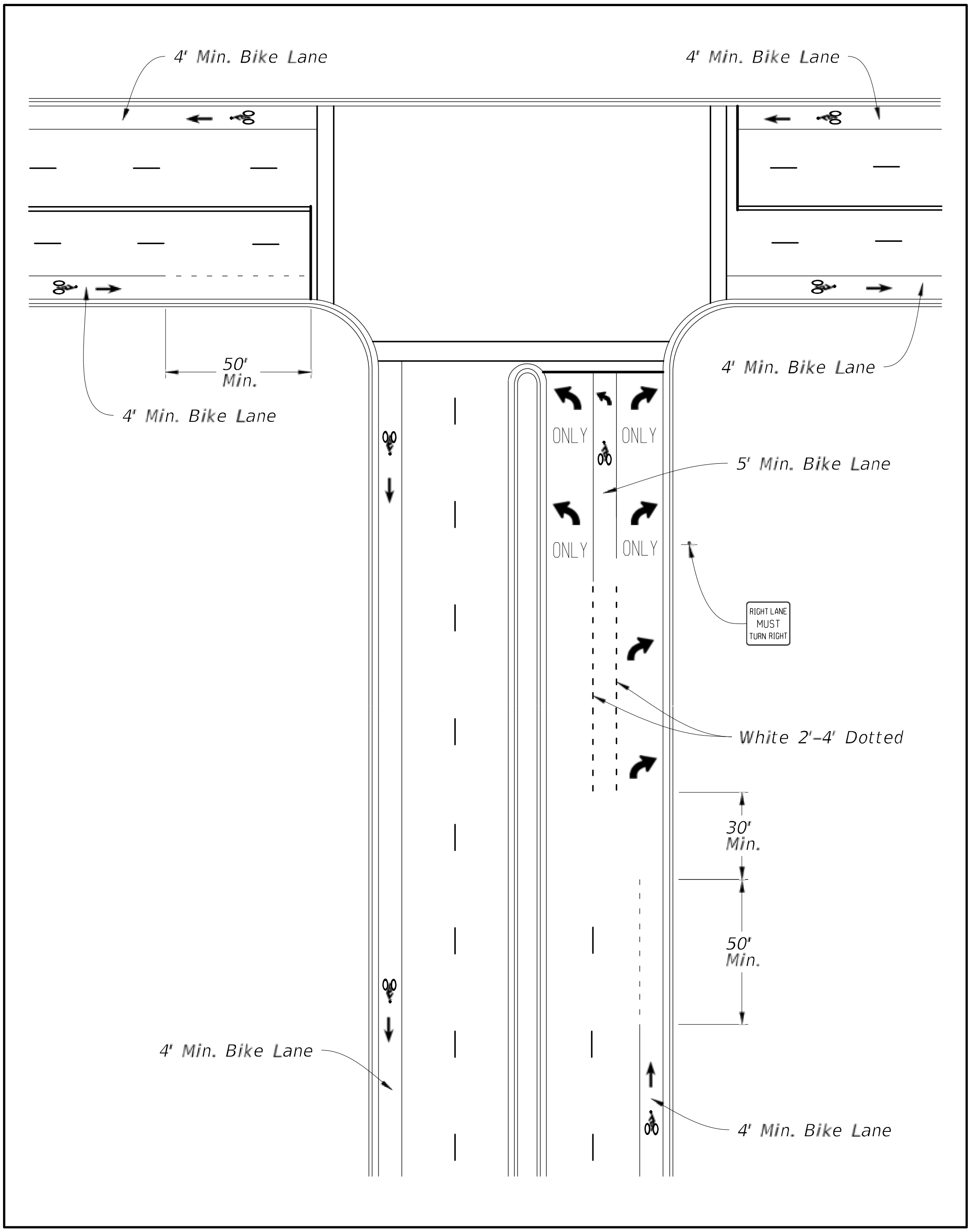
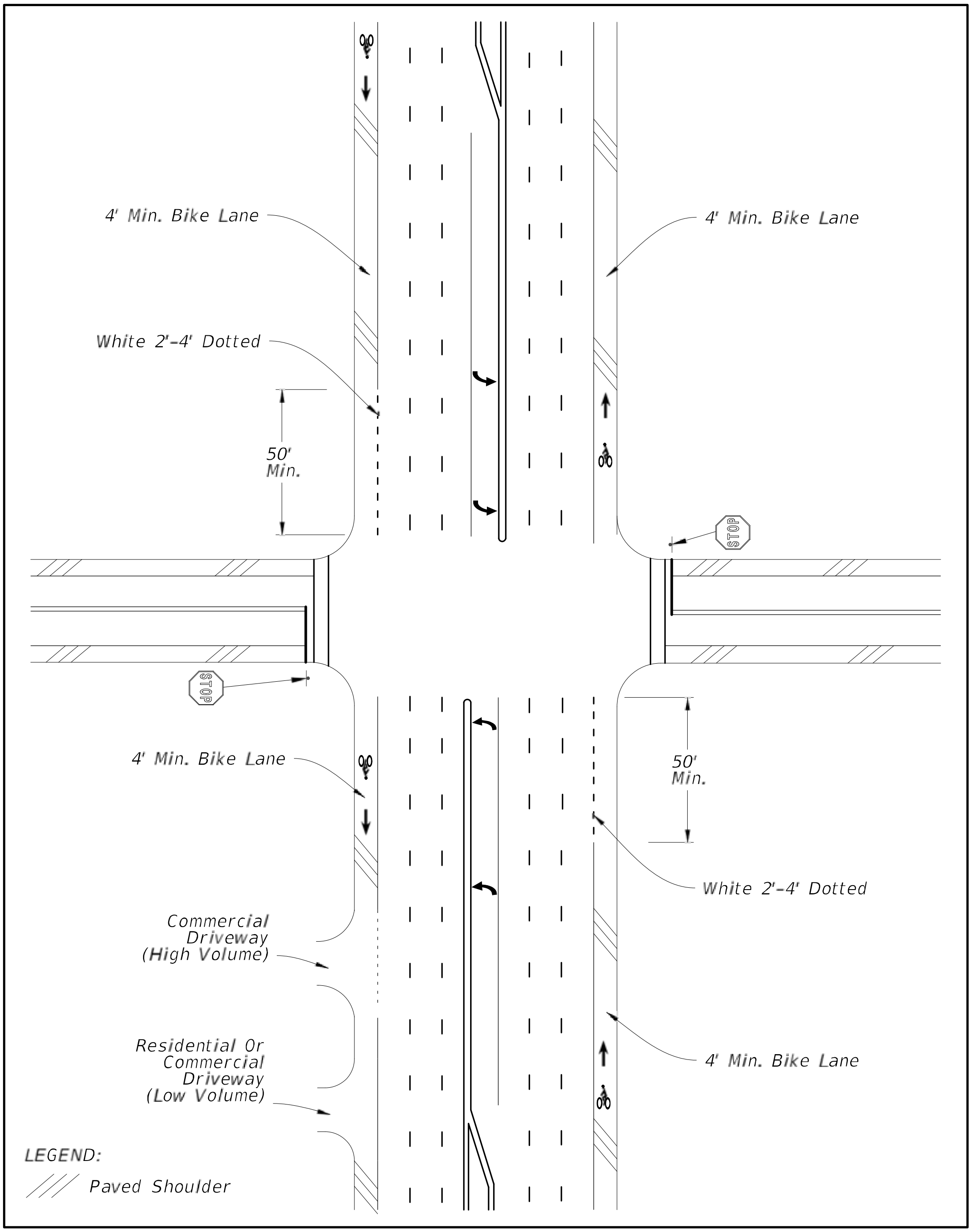


**Figure 9 – 12 Bicycle Lanes with No Right Turn Lane (Flush Shoulder)**



## Figure 9 – 13 Bicycle Lane with Separate Right Turn Lane (Flush Shoulder)

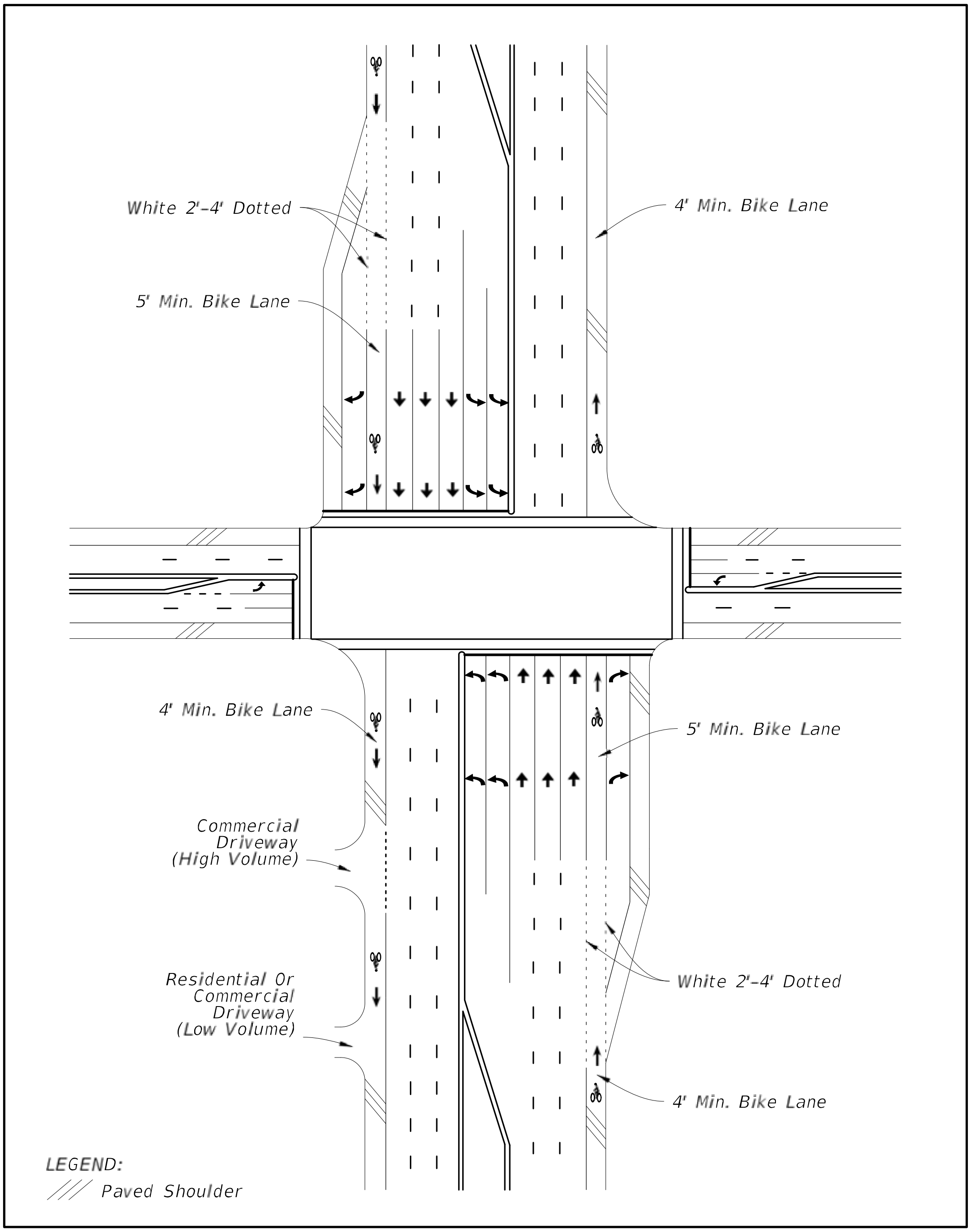


**Figure 9 – 14 Bicycle Lanes with Bus Bay, No Right Turn Lane (Curb and Gutter)**

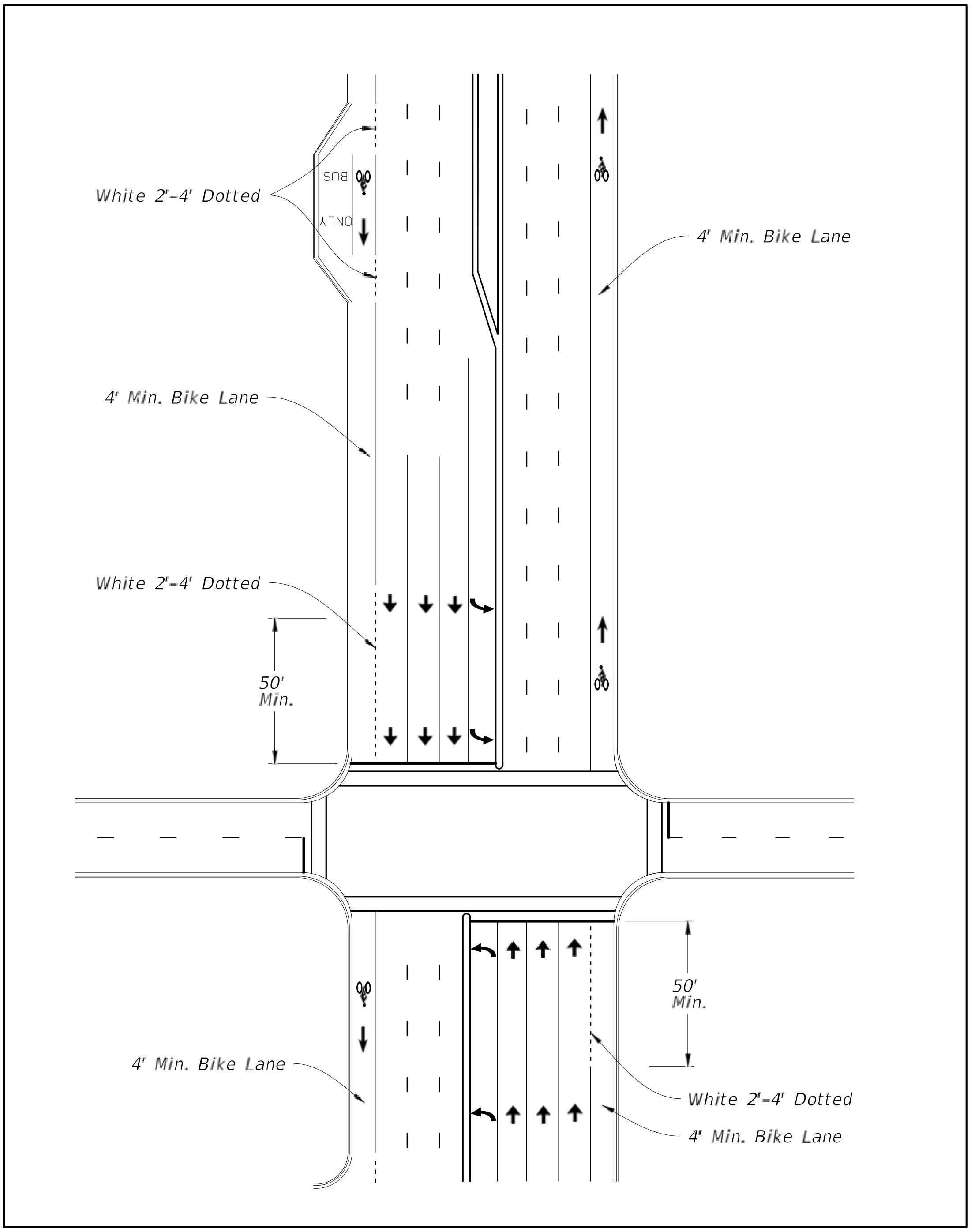
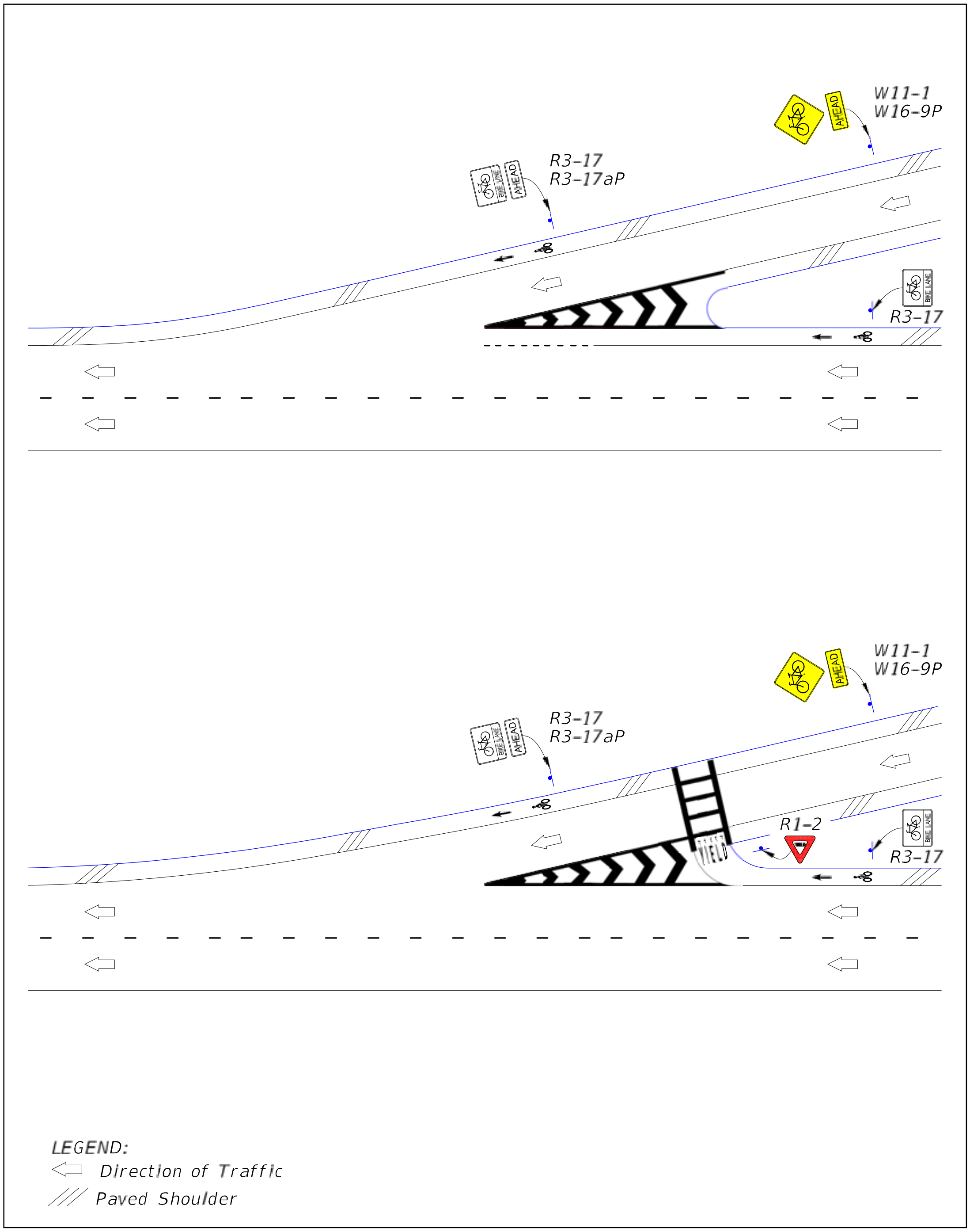


**Figure 9 – 15 Bicycle Lanes on Interchange Ramps (Flush Shoulder)**



## B.2 Buffered Bicycle Lanes

Buffered bicycle lanes are bicycle lanes separated from either the adjacent travel lane or parking lane with a marked buffer area. They provide greater shy distance between motor vehicles and bicyclists and encourage bicyclists to ride outside of the "door zone" of parked cars. Typical applications include streets with high travel speeds, high traffic volumes, high amounts of truck or transit traffic, or where there are underutilized travel lanes or extra pavement width.

The bicycle lane symbol and arrow markings shall be used, along with longitudinal lines to create the buffer. There are several options for marking the buffer area, including a wide solid double line (crossing prohibited), wide solid single line (crossing discouraged) or wide dotted single line (crossing permitted to make right hand turn). Where the buffer space is wider than 4 feet and crossing the buffer is prohibited, chevron markings should be placed in the buffer area.

At an intersection approach, the buffer striping should transition to a wide dotted stripe using a 2/4 skip pattern. The transition should begin 150 feet in advance of an intersection to provide sufficient distance for an automobile or truck to merge into the bicycle lane before turning right. Figures 9 – 16, 17 and 18 provide examples of buffered bicycle lanes. ***Chapter 3D. Markings for Preferential Lanes*** of the ***MUTCD*** provides additional information on the striping of buffered bicycle lanes.

**Figure 9 – 16 Buffered Bicycle Lane Adjacent to On-Street Parking**

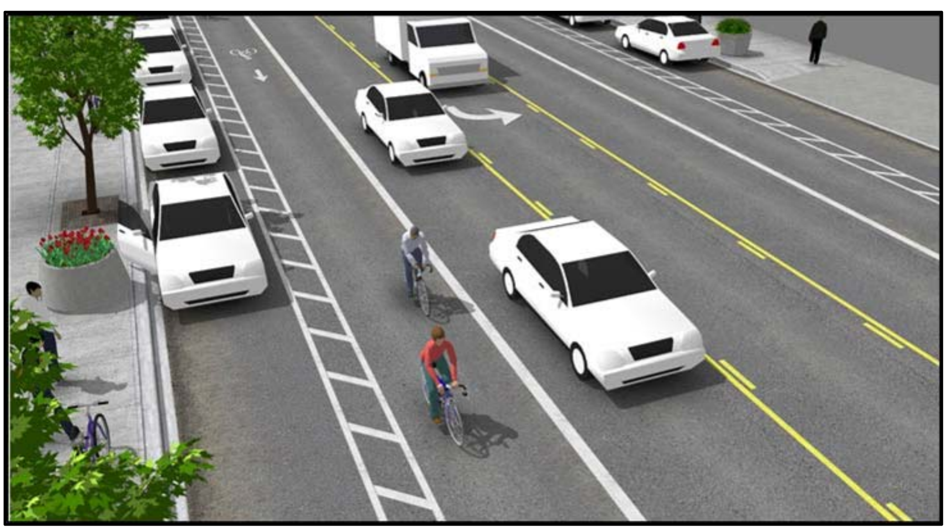


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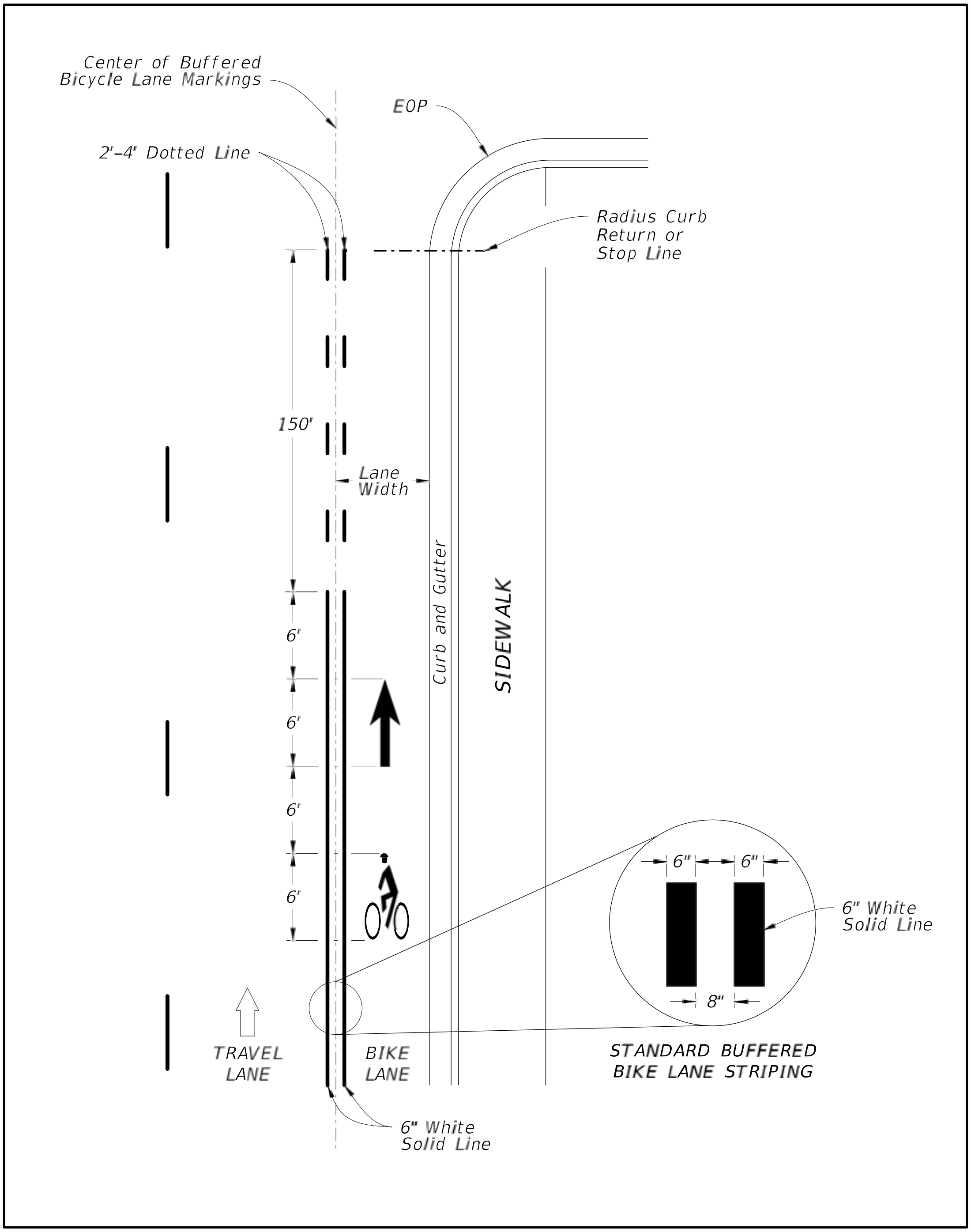
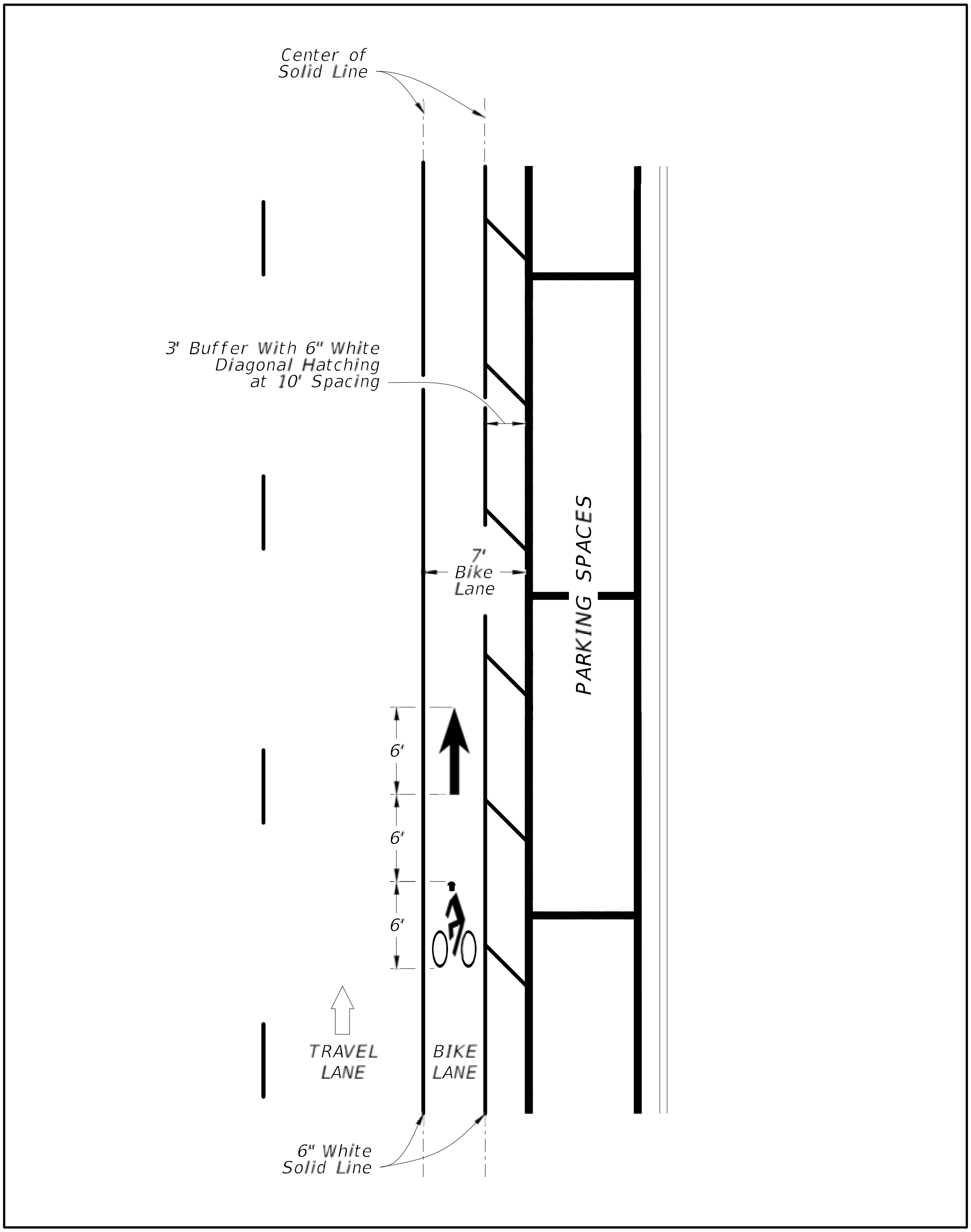
**Figure 9 – 17 Buffered Bicycle Lane Markings**



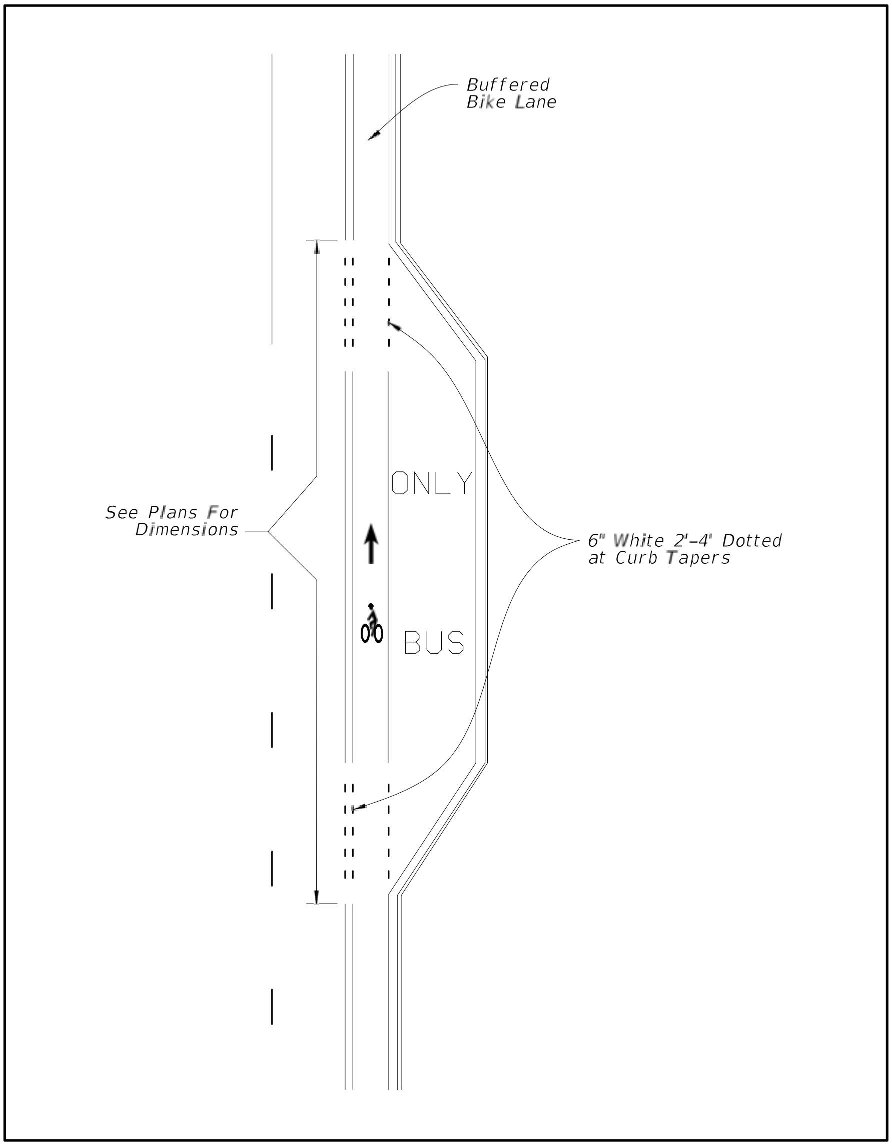
## Figure 9 – 18 Buffered Bicycle Lane Markings with On-Street Parking



## B.3 Bicycle Lane with Bus Bay

When a bus bay is provided on roadways with bicycle lanes, the bicycle lane shall be continued adjacent to the bus bay. Figure 9 – 19 Buffered Bicycle Lane with Bus Bay Marking provides an example of a buffered bicycle lane with a bus bay.

**Figure 9 – 19 Buffered Bicycle Lane with Bus Bay Marking (Curb and Gutter)**



## B.4 Green Colored Bicycle Lanes

The Federal Highway Administration (FHWA) has issued an Interim Approval for the use of green colored pavement in bicycle lanes and in extensions of bicycle lanes through intersections and other traffic conflict areas. Colored pavements shall not replace or be used in lieu of required markings for bike lanes as defined in the ***MUTCD***, but shall only supplement such markings. Traffic conflict areas include where the:

- bicycle lane crosses a right turn lane,
- traffic in a right turn lane crosses a bike lane, or
- bicycle lane is adjacent to a dedicated bus bay.

The Interim Approval may be found at the following website and provides further information on how to submit a written request to use green colored pavement:

*http://mutcd.fhwa.dot.gov/res-interim_approvals.htm*

The effectiveness of green colored pavement may be maximized if the treatment is used only where the path of bicyclists and other road users cross and yielding must occur. Because colored pavements are addressed in the 2009 MUTCD, they are by definition a traffic control device whose need should be demonstrated before they are used. A need for this treatment can be demonstrated by either of the following:

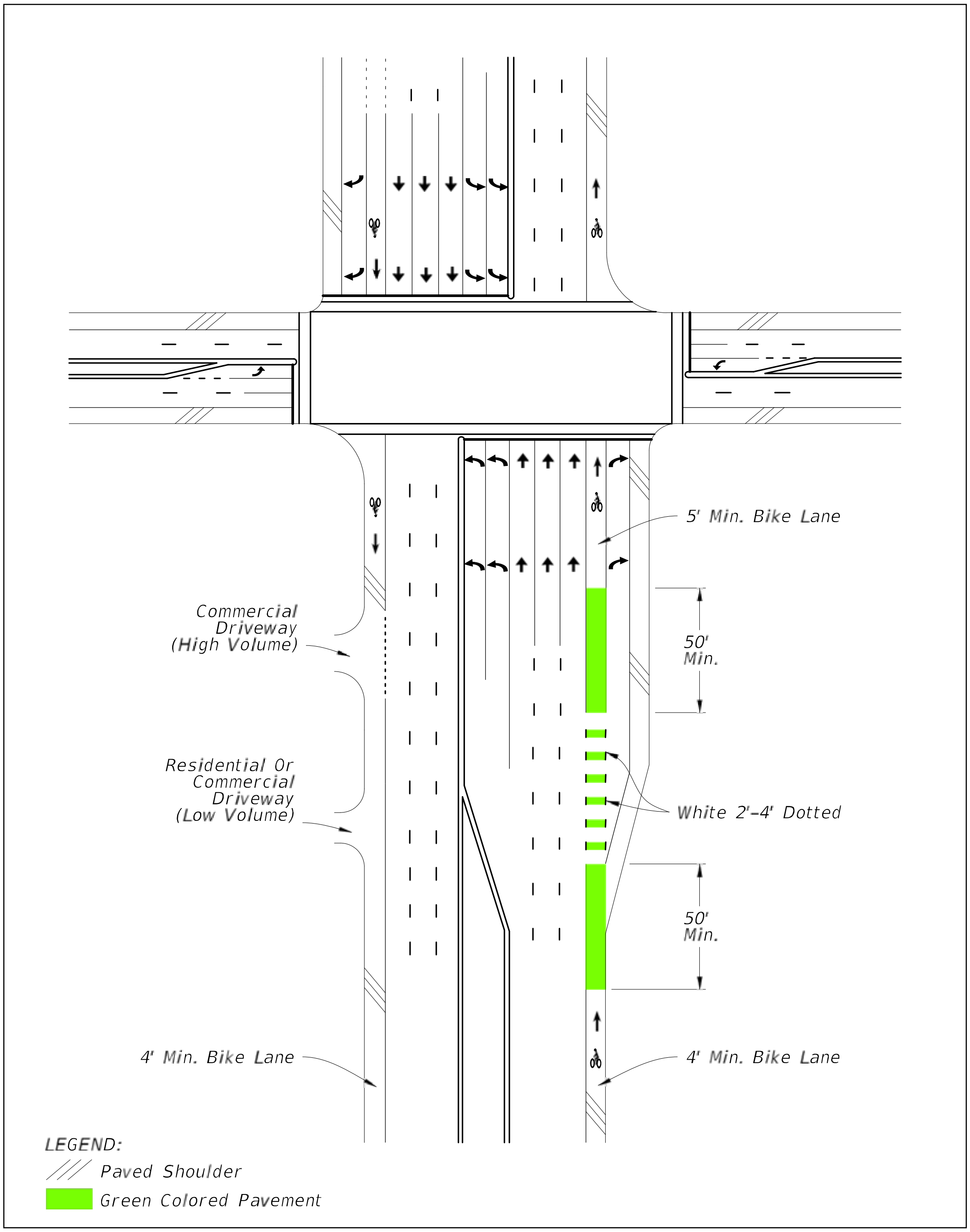
1. A history of 3 or more motor vehicle-bicycle crashes exists at or adjacent to the traffic conflict area over the most recent three-year period, or
2. A government agency has observed and documented conflicts (failure of the motor vehicle to yield to the bicyclist) between cyclists and motor vehicles at an average rate of two per peak hour. The documentation for conflicts shall include observations from a minimum of two separate data collection periods, conducted on different days in a one month period, and include at least one weekday and one weekend count period during peak bicycle travel times. Each period should be at least 2 hours in duration. Peak times vary by region and surrounding land use, but are typically:

    - Weekday, 11:00 AM to 1:00 PM
    - Weekday, 5:00 PM to 7:00 PM
    - Saturday, 8:00 AM to 2:00 PM

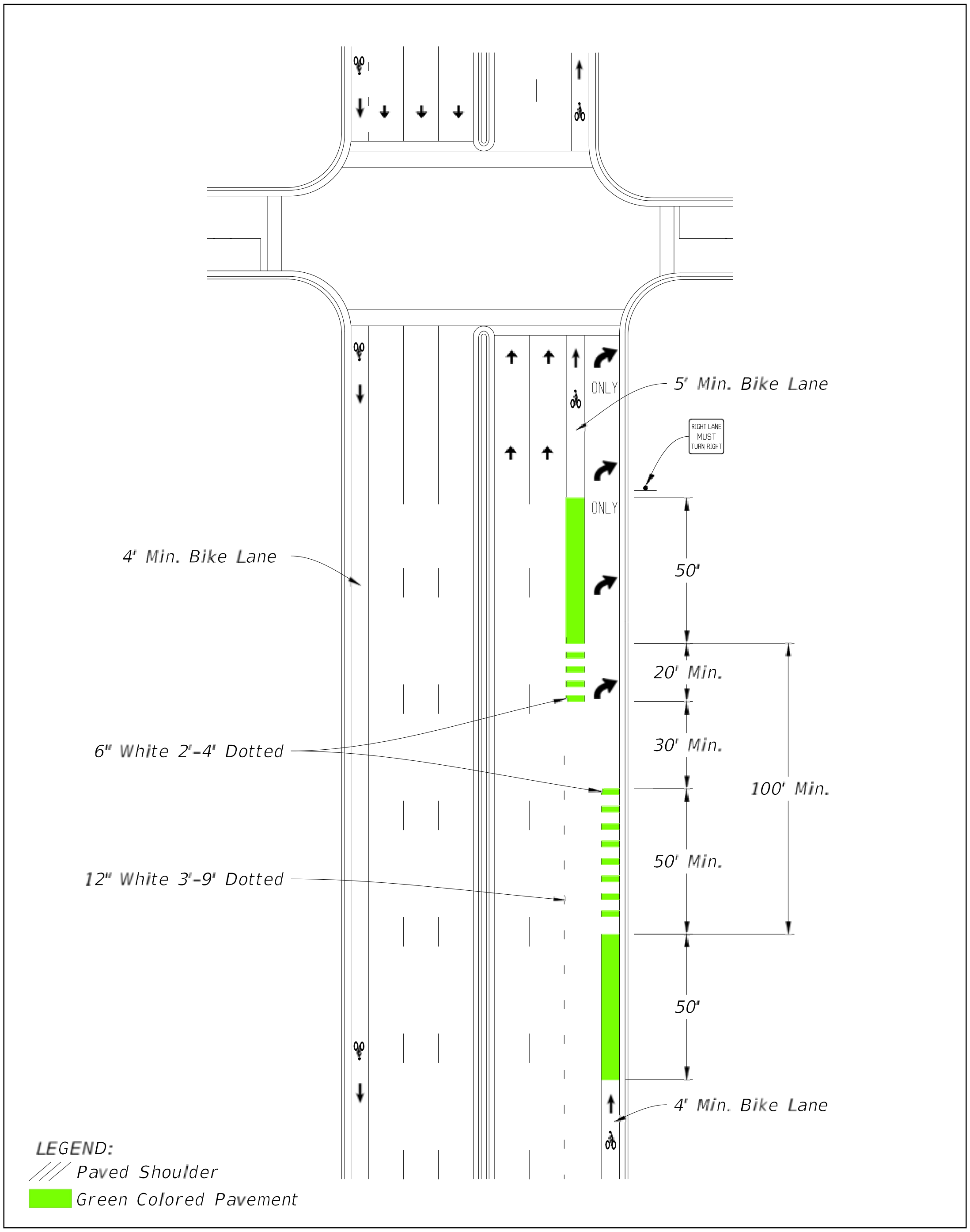
When used in conjunction with white skip lines, such as when extending a bike lane across a right turn lane or access to a bus bay, the transverse colored marking shall match the 2' - 4' white skip line pattern of the bike lane extension. The green colored pavement should begin as a solid pattern 50 feet in advance of the skip striping, match the 2' - 4' skip through the conflict area, and then resume the solid color for 50' after the conflict area, unless such an extent is interrupted by a stop bar or an intersection curb radius. Details of each installation and associated pavement markings shall be shown in the plans. Figures 9 – 20, 21, 22 and 23 illustrate how the green portion of the bicycle lane may be marked.

Materials permitted to color the bike lane green shall be non-reflective and fall within the color parameters defined by FHWA in their interim approval. Materials which have been tested to meet these requirements can be found in ***FDOT's Approved Product List for Specification 523, Patterned Pavement.***

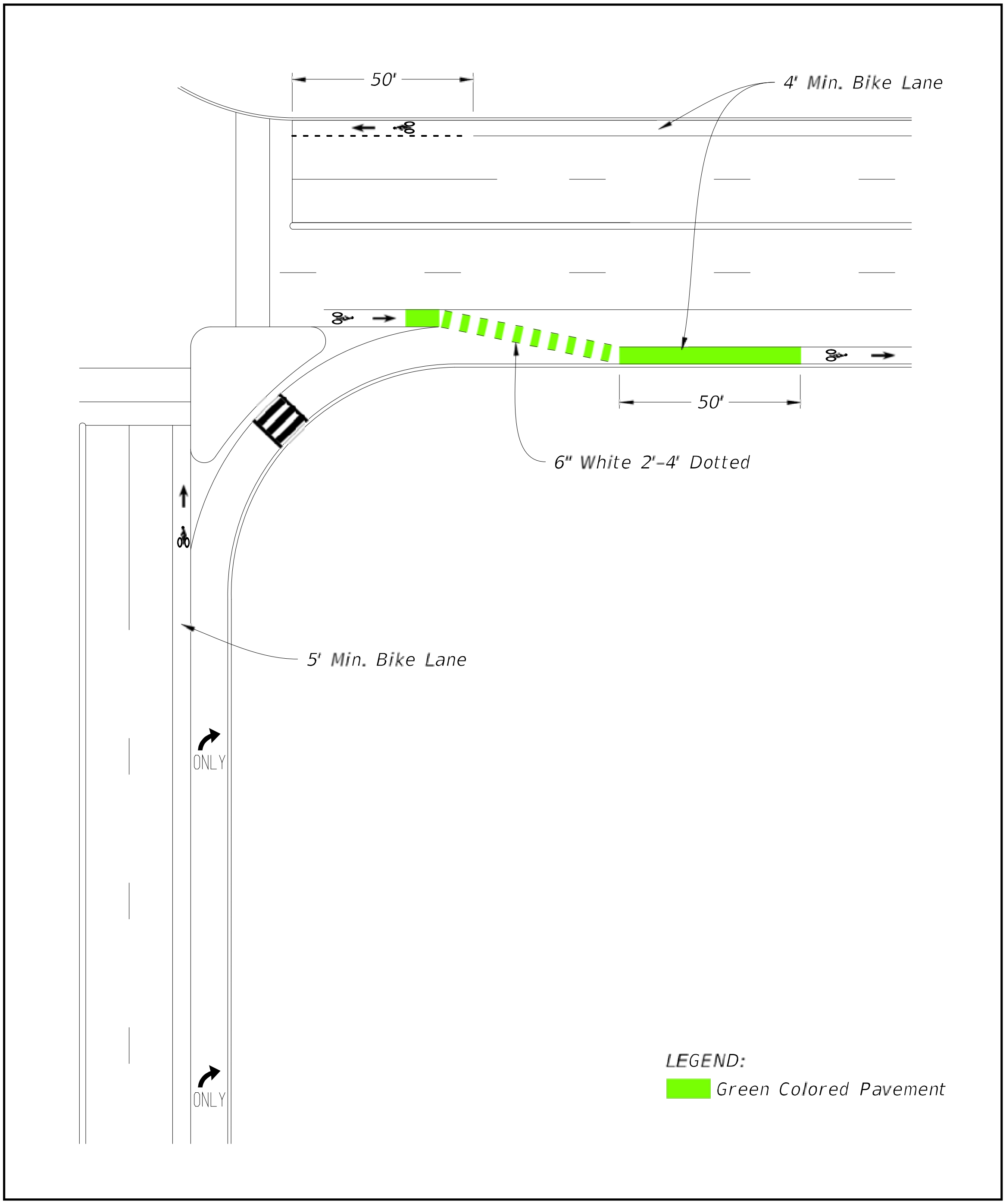
## Figure 9 – 20 Green Bicycle Lane with Separate Right Turn Lane



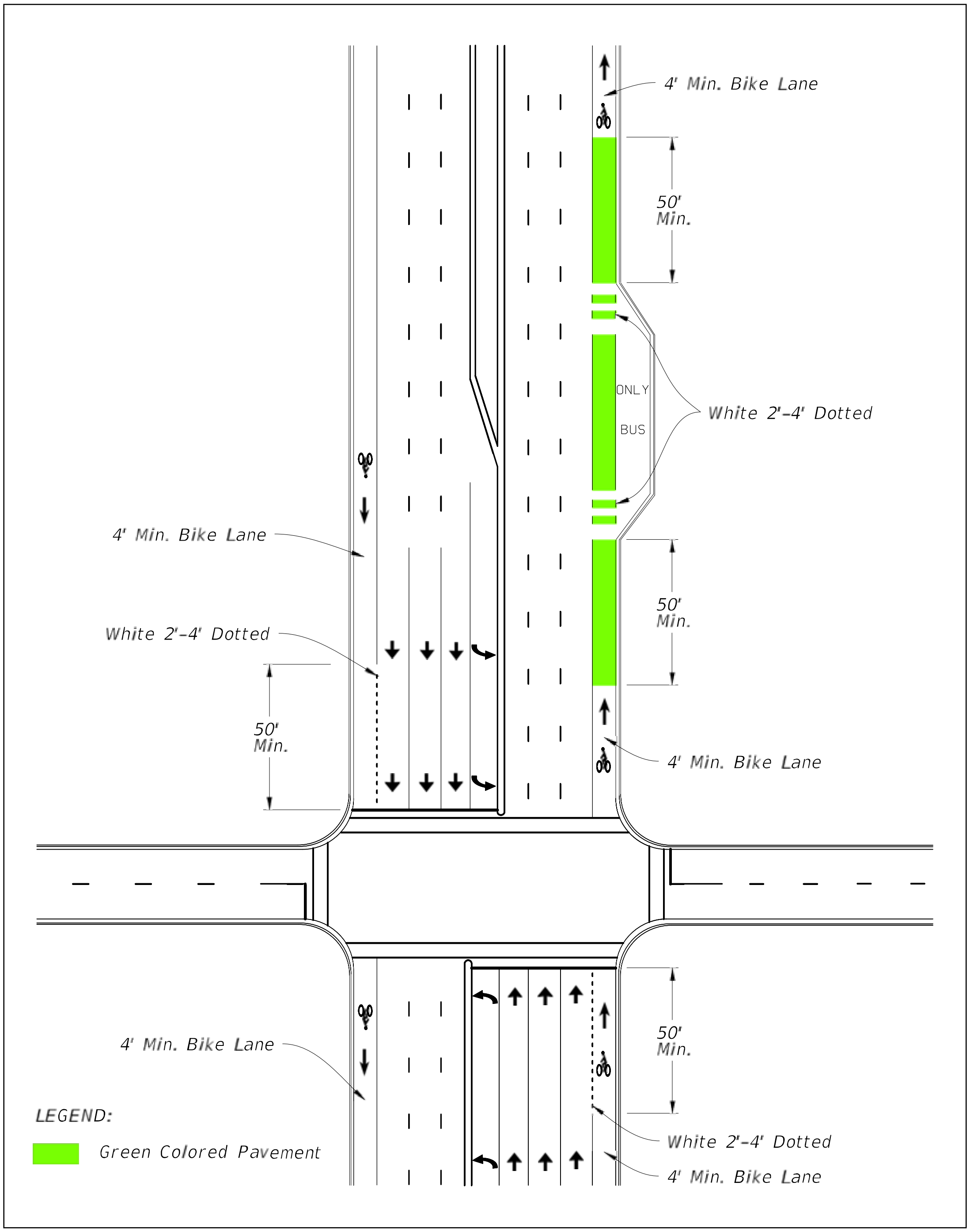
## Figure 9 – 21 Green Bicycle Lane with Right Turn Drop Lane



## Figure 9 – 22 Green Bicycle Lane with Channelized Right Turn Lane



# Figure 9 – 23 Green Bicycle Lane with Bus Bay



## B.5 Paved Shoulders

A paved shoulder is a portion of the roadway which has been delineated by edge line striping. Adding, widening or improving paved shoulders often can be an acceptable way to accommodate bicyclists. However, when a shoulder is intended to serve as a bicycle facility and is adjacent to a curb, guardrail or other roadside barrier, a minimum 5-foot clear width between the traveled way and the face of the barrier is required. Additional shoulder width is desirable if the posted speed exceed 50 mph, or the percentage of trucks, buses, or recreational vehicles is high (>10%).

Ground-in rumble strips should not be included in paved shoulders if a minimum clear width of 4 feet outside of the rumble strip cannot be provided.

## B.6 Wide Outside Lanes

Wide outside lanes on curbed roadways are through lanes that provide a minimum of 14 feet in width, which allows most motor vehicles to pass cyclists safely within the travel lane. Bicycle lanes are preferred for arterial and collector roadways, however, in some conditions, such as resurfacing projects, wide outside lanes may be the only practical option for a bicycle facility.

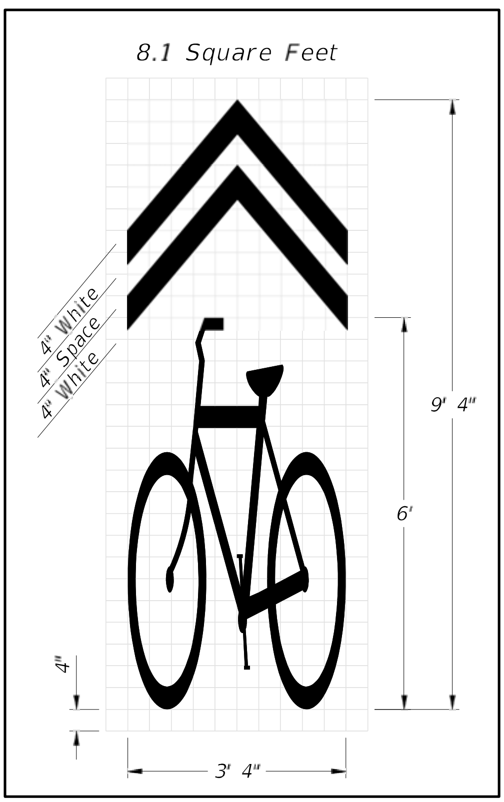
## B.7 Shared Lane Markings

The shared lane marking is an optional pavement marking for roadways where bicyclists and motor vehicles are intended to share the lane and no bicycle lane or paved shoulder exists or is feasible. Shared lane markings should be limited to roadways with a posted speed of 35 mph or less. They are not intended to be placed on every roadway without bicycle facilities or on shared use paths.

Shared lane markings provide guidance to cyclists on their lateral positioning, especially on roadways with on-street parking or lanes that are too narrow to share side by side with a motor vehicle. They also help to discourage wrong way riding and encourage safer passing of bicyclists by motorists. Shared lane markings may be used to identify an alternate route as part of an approved temporary traffic control plan. Figure 9 – 24 provides the dimensions for shared lane markings.

Shared lane markings should be placed as follows:

**Figure 9 – 24 Shared Lane Marking**




- If used on a roadway without on-street parking that has an outside travel lane that is 14 feet wide or less, the Shared Lane Markings should be centered in the travel lane (Figure 9 – 25).
- If used on a roadway with on-street parking, the Shared Lane Markings should be centered in the travel lane (Figure 9 – 26).
- Shared Lane Markings should be placed immediately after an intersection and spaced at intervals not greater than 250 feet thereafter.

**Figure 9 – 25 Shared Lane Marking Placement**
**(No Designated Parking, Lane Width ≤ 14 Feet)**

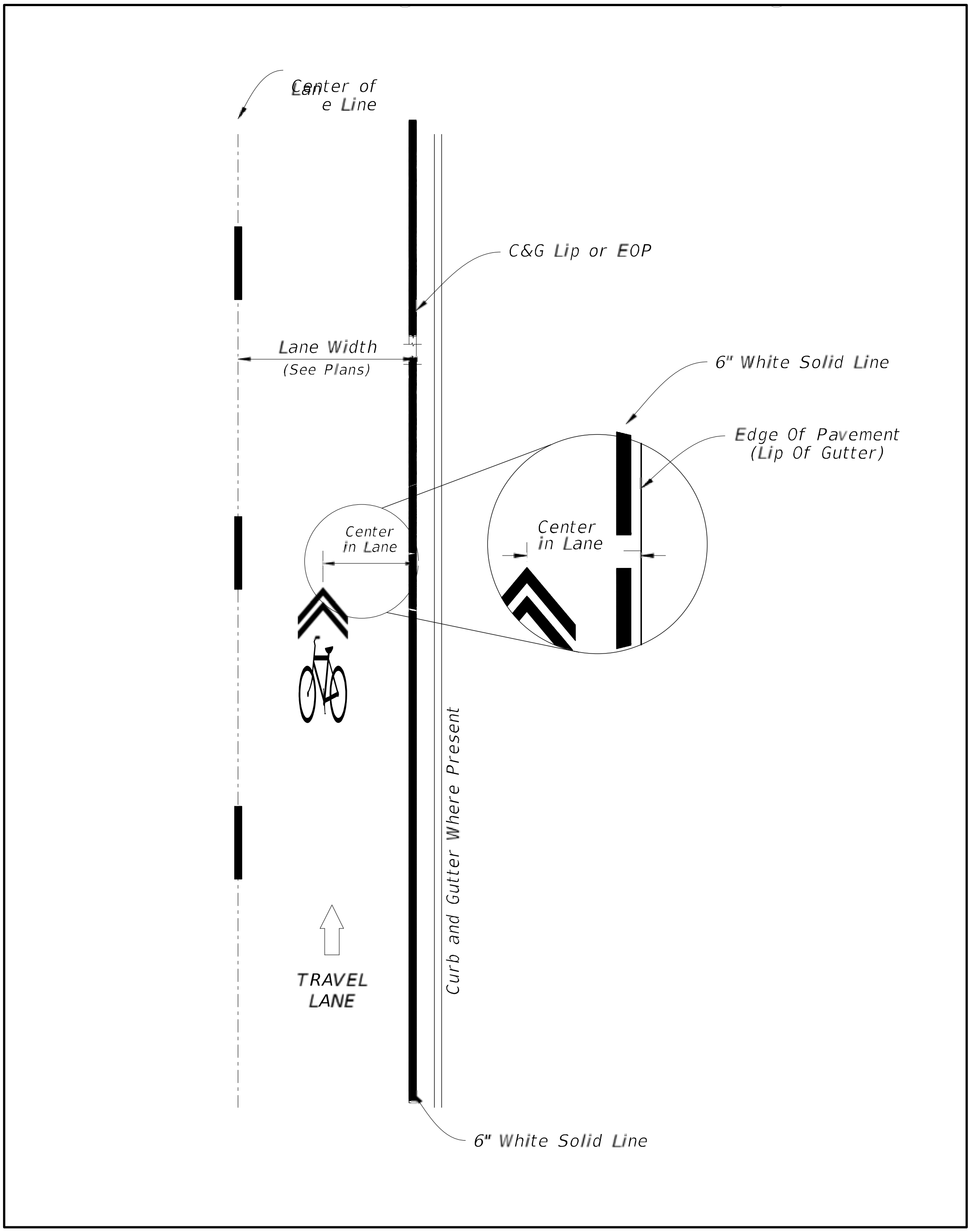


**Figure 9 – 26 Shared Lane Marking Placement (With On-Street Parking)**