While shielding bridge piers to protect motorists from a hazard within the clear zone is often necessary, some bridge piers may need shielding for protection from damage due to design limitations (i.e. piers not designed for vehicular collision forces). Coordination with the Structural Engineer of Record is required to determine if pier protection is warranted. The Department's ***Standard Plans, Index 521-002*** provides details for crashworthy Pier Protection barriers and the ***Design Manual***, Chapter ***215 Roadside Safety*** provides a process for determining the appropriate level of pier protection. As with median and shoulder concrete barrier walls, the Department is replacing the F-Shape pier protection barriers that have been in use for several years with single slope face systems.

E.8.c High Tension Cable Barrier

There are a variety of crash tested flexible barrier systems using w-beam and cable, but they historically have not been in common use in Florida. In recent years several proprietary high-tension cable barrier (HTCB) systems have been developed that meet NCHRP Report 350 and MASH criteria. These systems are installed with a significantly greater tension in the cables than the generic low-tension systems that have been used in some states for many years. High tension cable barrier systems may be used for both median and roadside application. Deflection space requirements are dependent on the system, system length and post spacing, and are significantly greater than semi-rigid systems.

High tension cable barrier has shown to have several advantages over other types of flexible barrier systems. One advantage is they tend to result in less damage when impacted. Another is that certain systems have been tested for use on slopes as steep as 1:4. Still another advantage is that in many cases, the cables remain at the proper height after an impact that damages several posts. While no manufacturer claims their barrier remains functional in this condition, there is the potential that this offers a residual safety value under certain crash conditions. Posts are typically lightweight and can be installed in cast or driven sockets in the ground to facilitate removal and replacement. One disadvantage is that each vendor uses a different post design and cable arrangement, and therefore posts are not interchangeable between systems manufactured by different vendors.

The Department has used High Tension Cable Barrier (HTCB) in selected locations and continues to install these systems using the Department's *Developmental Design Standards and Developmental Specifications (DDS)* process. Detailed information on the usage requirements and design criteria of HTCB can be found on the *Department's DDS* website.

It includes the following:

Developmental Standard Plans Instructions D 540-001

Developmental Standard Plans Index D 540-001

Developmental Specification, Dev540

E.8.d Temporary Barrier

As stated in Section E.5.e, temporary barriers are used primarily in work zones for several purposes. The most commonly used temporary barriers in Florida are those adopted for use by FDOT. The department's temporary barriers include:

Low Profile Barrier – Standard Plans, Index 102-120 (TL-2, NCHRP 350)

Type K Barrier – Standard Plans, Index 102-110 (TL-3, NCHRP 350)

Proprietary Temporary Barrier –Standards Plans, Index 102-100 and the *Approved Products List (APL)* (TL-2 & TL-3, NCHRP 350)

Additional information on the proper use of these barriers is provided in the Department's *Design Manual* and the Vendor drawings on the *Approved Products List*.

Additional information on temporary barrier systems meeting *NCHRP Report 350* and/or MASH criteria can be found in the *Manual for Assessing Safety Hardware* and the *AASHTO Roadside Design Guide*.

E.8.e Selection Guidelines

The evaluation of numerous factors is required to ensure that the appropriate barrier type is selected for a given application. Consideration should be given to the following factors when evaluating each site:

- Barrier Placement requirements (see Section E.6.f)
- Traffic characteristics (e.g. vehicle types/percentages, volume, and growth)
- Site characteristics (e.g. terrain, alignment, geometry, access facility type, access locations, design speed, etc.)
- Expected frequency of impacts
- Initial and replacement/repair costs
- Ease of maintenance
- Exposure of workers when conducting repairs/maintenance
- Aesthetics

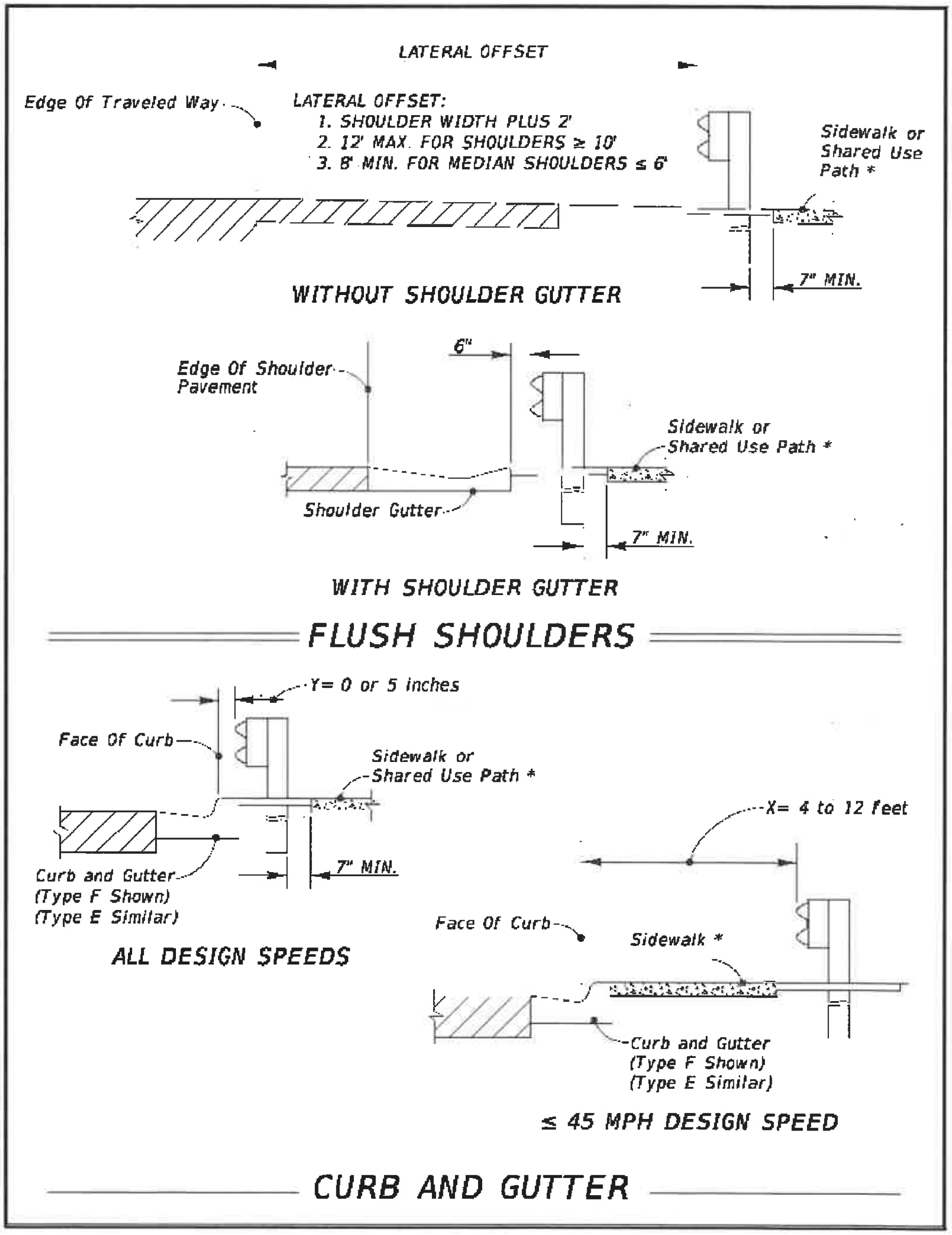
For additional information about considerations for barrier selections refer to the *AASHTO Roadside Design Guide*. Barrier type selection decisions and warrants should be documented.

E.8.f Placement

E.8.f.1 Barrier Offsets

Roadside barriers should be offset as far from the travel lanes as practical with consideration for maintaining the proper performance of the barrier. For the barriers described above see the Department's *Design Manual, Chapter 215 Roadside Safety* and *Standard Plans* for proper barrier placement. Figure 4 – 8 Location of Guardrail provides information on the offset of guardrail on curbed and flush shoulder roadways.

Figure 4 – 8 Location of Guardrail



* When a sidewalk is present or planned. See Chapter 8 – Pedestrian Facilities and Chapter 9 – Bicycle Facilities for criteria for sidewalks and shared use paths (e.g. width of facility plus clear, graded areas adjacent to the path or sidewalk).

E.8.f.2 Deflection Space and Zone of Intrusion

In addition to travel lane lateral offset considerations, an adequate setback must be provided behind the barrier to ensure proper function. For flexible and semi-rigid barriers, the setback is based on deflection tolerances and is required to prevent the barrier from contacting aboveground objects.

For rigid barriers, the setback is required to keep the area above and behind the barrier face free of obstructions that could penetrate or damage the vehicle compartment. This requirement is based on the Zone of Intrusion (ZOI) concept as described in the ***AASHTO Roadside Design Guide.***

These requirements do not apply to devices located within the setback distances detailed in the Department's ***Standard Plans*** (e.g. pedestrian/bicycle railing, fencing, noise walls, etc.).

E.8.f.3 Grading

The terrain effects between the traveled way and a barrier can have a significant impact on whether a barrier will perform as intended. Proper grading around a barrier will ensure that as a vehicle approaches a barrier its suspension is not dramatically affected, causing the vehicle to underride or override a barrier.

E.8.f.4 Curbs

As with grading, the presence of curb in combination with barriers deserves special attention. A vehicle which traverses a curb prior to impact may override the barrier if it is partially airborne at the moment of impact. Conversely, the vehicle may "submarine" under the rail element of a guardrail system and snag on the support posts if it strikes the barrier too low..

E.8.f.5 Flare Rate

A flared roadside barrier is when it is not parallel to the edge of the traveled way. A flared barrier may be necessary for several reasons:

- To locate the barrier terminal farther from the roadway
- To minimize a driver's reaction to an obstacle near the road by gradually introducing a parallel barrier installation
- To transition a roadside barrier to an obstacle nearer the roadway such as a bridge parapet or railing
- To reduce the total length barrier needed.
- To reduce the potential for barrier and terminal impacts and provide additional roadside space for an errant motorist to recover.

A concern with flaring a section of roadside barrier is that the greater the flare rate, the higher the angle at which the barrier can be hit. As the angle of impact increases, the crash severity increases, particularly for rigid and semi-rigid barrier systems. Another disadvantage to flaring a barrier installation is the increased likelihood that a vehicle will be redirected back into or across the roadway following an impact.

For the barriers described above, see the Department's ***Design Manual, Chapter 215*** **Roadside Safety** for acceptable flare rates. Additional information on flare rates are provided in the ***AASHTO Roadside Design Guide.***

E.8.f.6 Length of Need

The length of need for a particular barrier type is calculated based on several factors including the length of the hazard, the lateral area of concern, run out length and other factors. Length of need must consider traffic from both directions.

A spreadsheet tool for calculating length of need is provided on the Department's ***Standard Plans*** web page, adjacent to ***Index 536-001*** in the ***Design Tools*** column. Additional information on length of need is provided in the ***AASHTO Roadside Design Guide.***

E.8.g Barrier Transitions

Guardrail transitions are necessary whenever standard W-Beam guardrail converges with rigid barriers. The purpose of the transition is to provide a gradual stiffening of the overall approach to a rigid barrier so that vehicular pocketing, snagging, or penetration is reduced or avoided at any position along the transition. Guardrail transitions must include sound structural connections, nested panels and additional posts for increased stiffness. The Department's ***Standard Plans*** provide details for several transitions for both permanent and rigid barriers that meet MASH criteria. Additional information on transitions is provided in the Department's ***Design Manual, Chapter 215 Roadside Safety*** and the ***AASHTO Roadside Design Guide.***

E.8.h Attachments to Barriers

Attachments to barriers such as signs, light poles, and other objects will affect crash performance and should be avoided where practical. Attachments not meeting the requirements discussed in Section E.6.f

Placement, should meet crash test criteria. See the ***Department's Design Manual, Chapter 215 Roadside Safety*** for additional information on attachments to barriers.

E.9 End Treatments and Crash Cushions

As previously discussed, end treatments include end anchorages, end terminals, and crash cushions. Details for end treatments for each barrier type described above are detailed in the Department's ***Standard Plans*** and the ***Approved Products List (APL)***.

E.9.a End Treatments for Guardrail

End treatments for guardrail are categorized as follows:

1. Approach end terminals – required for guardrail ends within the clear zone of approaching traffic. The Department's guardrail approach end terminals are proprietary devices listed on the ***APL***. Approach end terminals are classified by Test Level (TL-2 for Design Speeds ≤ 45 mph or TL-3, which is acceptable for all Design Speeds) and as follows:
    a. Flared – preferred terminal for locations where sufficient space is available to offset barrier end from approaching traffic.
    b. Parallel – use only when sufficient space is not available for a flared terminal.
    c. Double Face – preferred end treatment for double faced guardrail installations.
2. Crash Cushions – See Section E.7.e.
3. Trailing End Anchorages (Type II) – required for anchoring of the trailing ends of guardrail. Trailing End Anchorages are considered non-crashworthy as an approach end treatment, and are not permitted as guardrail end treatments on the approach end within the Clear Zone, unless shielded by another run of barrier. The Department's Type II Trailing End Anchorage, is detailed in the Standard Plans, Index 536001

Additional information on guardrail end treatments is provided in the Department's ***Design Manual, Chapter 215 Roadside Safety***.

E.9.b End Treatments for Rigid Barrier

Rigid Barrier ends must be terminated by either transitioning into another barrier system (e.g. guardrail), or by shielding with a Crash Cushion. Details are provided in the Department's *Standard Plans*, ***Index 521-001*** . Treatment of the trailing end of rigid barriers is not required unless additional hazards exist beyond the rigid barrier or the barrier is within the clear zone of opposing traffic.

E.9.c End Treatments for High Tension Cable Barrier (HTCB)

End treatments for high tension cable barrier are vendor specific. For additional information regarding the end treatment of HTCB, refer to the Department's developmental design standards discussed above.

E.9.d End Treatments for Temporary Barrier

Details for end treatments for the Department's Temporary Barrier are provided in the Department's *Standard Plans* and include:

1. Connecting to an existing barrier. Smooth, structural connections are required. Information on connections can be found in the Department's *Standard Plans, Indexes 521-001* and *102-110* and *APL).*
2. Shield end with a crash cushion as detailed in the *Standard Plans,* ***Index 102 Series*** or ***APL*** for the specific type of Temporary Barrier (i.e. portable concrete barrier, steel, or water filled).
3. Attaching or Transitioning to a crashworthy end treatment as described above.
4. Flaring outside of the Work Zone Clear Zone.

E.9.e Crash Cushions

Crash cushions are classified based on Test Level and Design Speed which is shown for each system on each vendor's respective drawings posted on the Department's *APL.*

The design of a crash cushion system must not create a hazard to opposing traffic. The APL drawings provide details for transitions for optional barrier types with and without bi-directional traffic.

An impacting vehicle should strike the systems at normal height, with the vehicle's suspension system neither collapsed nor extended. Therefore, the terrain surrounding crash cushions must be relatively flat (i.e. 1:10 or flatter) in advance of and along the entire design length of the system. Curbs should not be located within the approach area of a crash cushion.

The *Department's* ***Design Manual,*** ***Chapter 215 Roadside Safety*** provides additional information on permanent and temporary crash cushions.

F BRIDGE RAILS

See ***Chapter 17 - Bridges and Other Structures*** for requirements for bridge rails. The *Department's* ***Design Manual,*** ***Chapter 215 Roadside Safety*** may be referenced for additional information and typical applications.

G REFERENCES

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

- AASHTO Roadside Design Guide
  https://bookstore.transportation.org/
- Task Force 13 Guide to Standardized Roadside Safety Hardware http://www.tf13.org/Guides/
- FHWA Web Site
  http://safety.fhwa.dot.gov/roadway_dept/
- FDOT Design Manual
  http://www.fdot.gov/roadway/FDM/
- FDOT Standard Plans for Road and Bridge Construction (Standard Plans) http://www.fdot.gov/design/standardplans/
- FDOT Structures Design Guidelines
  http://www.fdot.gov/structures/StructuresManual/CurrentRelease/StructuresManual.shtm
- FDOT Drainage Manual, January 2018
  http://www.fdot.gov/roadway/Drainage/ManualsandHandbooks.shtm
- Florida Strategic Highway Safety Plan 2016
  http://www.fdot.gov/safety/SHSP2016/SHSP-2012.shtm

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 this 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 the Department's ***Pavement Type Selection Manual (2013)***.

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: Reclaimed asphalt pavements (RAP) from milling operations 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 AASHTO's ***Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400), 2001*** and FHWA's ***Gravel Roads Construction and Maintenance Guide, August 2015*** 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. Where high ground water conditions are present, adequate clearance to the bottom of the pavement base is necessary for good pavement performance and to achieve the required compaction and stability during construction operations.

The Department's pavement design manuals, including the ***Flexible Pavement Design Manual, January 2018*** and ***Rigid Pavement Design Manual, January 2018***, 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 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 AASHTO's publication ***Guidelines for Geometric Design of Very Low-Volume Roads (ADT < 400), 2001*** and FHWA's ***Gravel Roads Construction & Maintenance Guide, August 2015*** 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

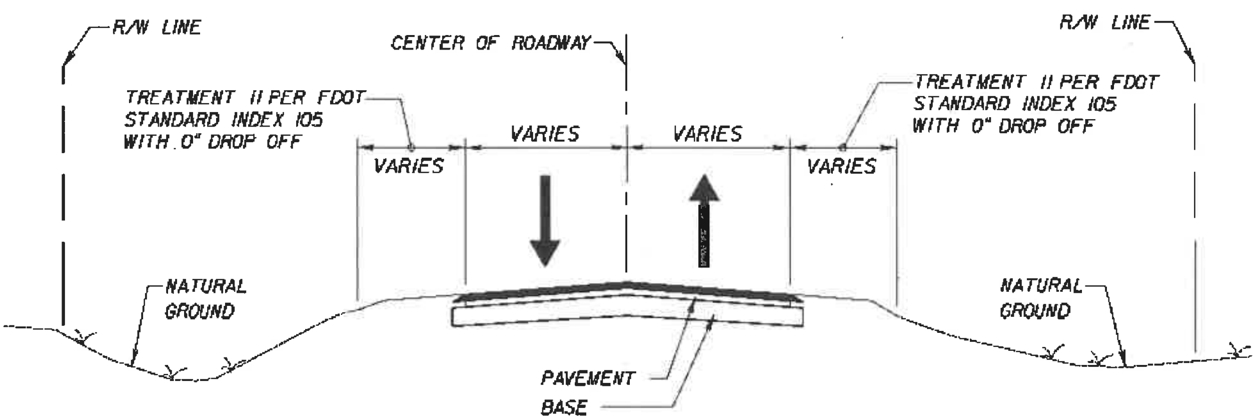
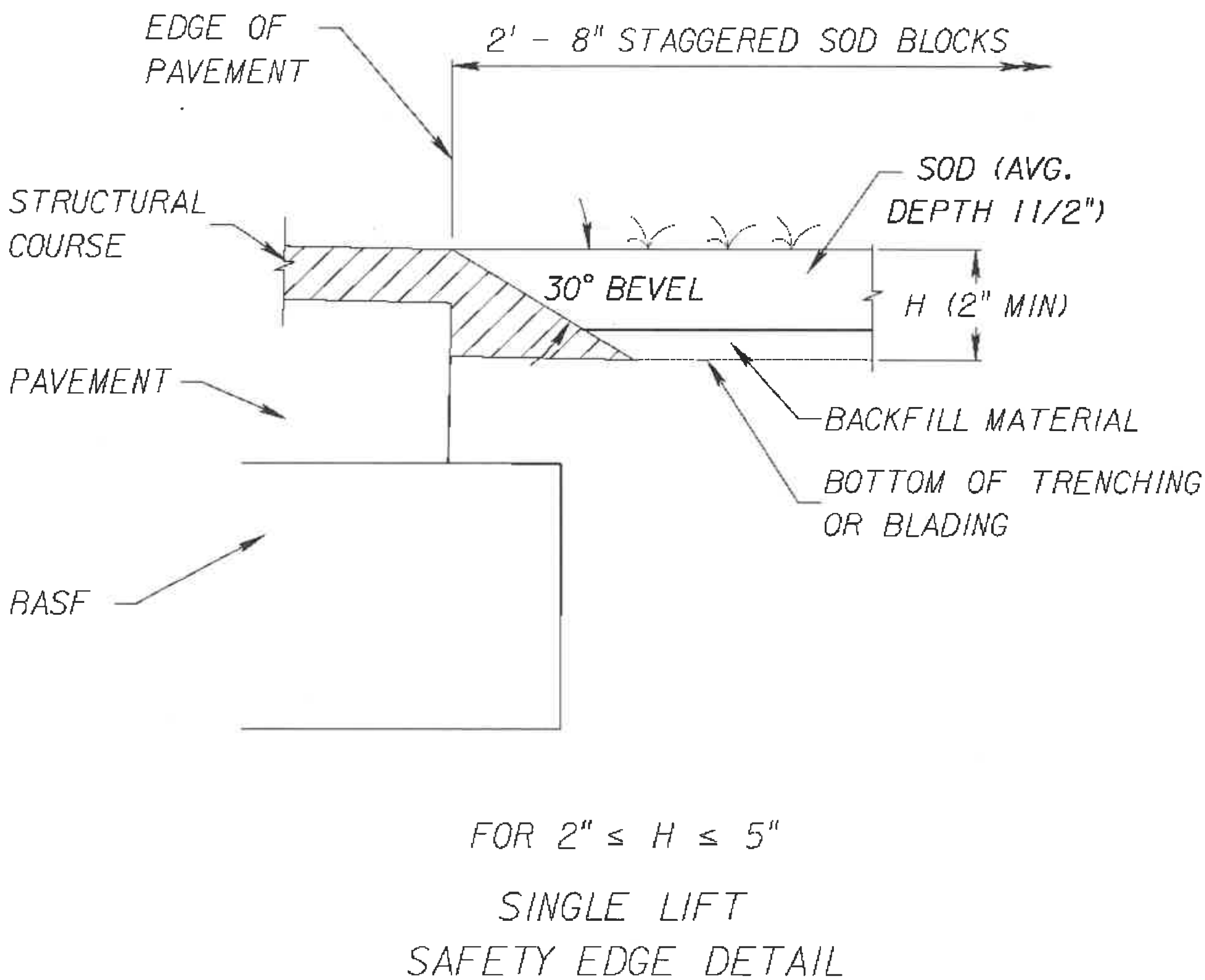


Figure 5 – 2
Safety Edge Detail (No Paved Shoulders)



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

FIGURES

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 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 to avoid glare or potential lighting distractions to drivers.

See ***Chapter 17 – Bridges and Other Structures, Section C.6*** for structural requirements for lighting.

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 new and reconstruction projects 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 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 and signalized intersections.
- Urban 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)
- Transit stops and hubs, passenger rail stations.
- Areas such as entertainment districts, sporting arenas, shopping centers, beach access points, parks, and other locations that generate higher volumes of pedestrian activity.
- Schools, places of assembly, , 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 LUMINAIRES

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.

- Light Emitting Diode (LED) – is the preferred light source for street lighting. 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. To provide sufficient lumen levels for roadway applications, most LED fixtures have an initial luminous efficiency of around 75 lumens per watt.

- High Pressure Sodium (HPS) Lamps –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 efficiency of over 100 lumens per watt.

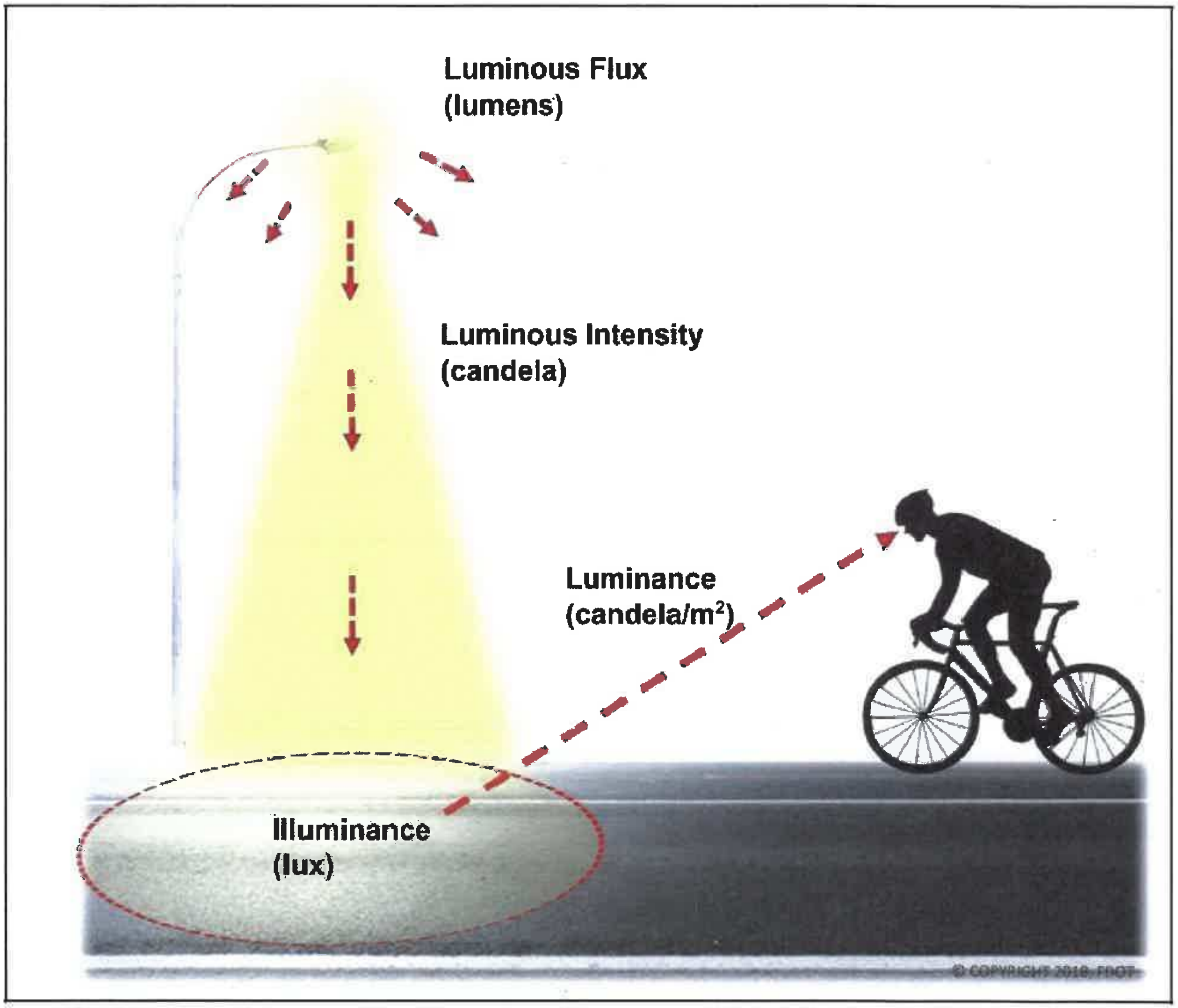
- Metal Halide (MH) Lamps – is used for overhead lighting of commercial parking lots, sports facilities, retail stores and street lighting. Light produced by MH lamps has a CCT of 3800°K to 4000°K which is a white color. The average rated life of a MH lamp can vary from 9,000 to 20,000 hours. MH lamps have a high initial luminous efficiency of around 75 - 100 lumens per watt.

E LIGHTING DESIGN TECHNIQUES

The accepted methods for achieving a given lighting condition are known as either level of illuminance or level of luminance. Both methods of calculation are dependent upon light being reflected toward the observer's eye. Horizontal illuminance is used for intersections and interchanges and includes a variable for surface type. Horizontal and vertical illuminance is the preferred method for pedestrian areas. The luminance method can be used for straight roadways and streets, based upon the appropriate choice of surface type.

Figure 6 – 1 Illuminance and Luminance illustrates how illuminance and luminance are measured. Illuminance is the measure of the amount of light flux falling on a surface and is measured in foot candles. Luminance is a measure of the amount of light flux leaving a surface and is measured in candelas per meter squared.

Figure 6 – 1 Illuminance and Luminance



E.1 Illuminance

When adding supplemental lighting for pedestrian activity, ensure lighting is compatible with any existing lighting in the corridor and minimizes glare. The illuminance method determines the amount of light falling on the roadway surface or on vertical surfaces from the roadway lighting system. Because the amount of light seen by the driver is the portion that reflects from the pavement towards the driver, and because different pavements exhibit varied reflectance characteristics, different illuminance levels are needed for each type of standard roadway surface. Illuminance is easily calculated and measurable and is not observer or pavement dependent.

E.2 Luminance

The luminance method determines how “bright” the road is by determining the amount of light reflected from the pavement in the direction of the driver. It uses the reflective characteristics (R-classification) noted in Table 6 – 1 Road Surface Classifications for the standard roadway surface types and a specific observer position.

The R-classification system is a measure of the lightness (white to black) and specularity (shininess) of roadway surfaces. 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***.

Table 6 – 1 Road Surface Classifications

Class	Q0*	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.). 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.

E.3 Lighting Design Levels

The level of illumination for streets and highways should not be less than those shown in Table 6 – 2 Illuminance and Luminance Design Values. When adding supplemental lighting for pedestrian activity, ensure lighting is compatible with any existing lighting in the corridor and minimizes glare.

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 – 2 Illuminance and Luminance Design Values

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 next page

Table 6 – 2
Illuminance and Luminance Design Values
(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.). 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

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.

The need for 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.

When lighting an underpass, use a wall-mounted luminaire that is attached to a pier, pier cap, or the wall copings underneath the bridge.

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. Consider daytime lighting for vehicles in underpasses greater than 80 feet in length.

Supplemental lighting of sidewalks or shared use paths in roadway underpasses less than 80 feet in length should be considered. Sidewalks and shared use paths on independent alignments with little natural light, especially if the exit is not visible upon entry. should be illuminated.

G.2 Night Lighting

The night time illumination level in the underpass of the roadway should be maintained near the night time level of the approach roadway. Lighting of sidewalks or shared use paths adjacent to roadways in underpasses should be considered. Sidewalks and shared use paths on independent alignments open to travel during darkness should be illuminated. .Due to relatively low luminaire mounting heights in underpasses, care should be exercised to avoid glare.

H DECORATIVE ROADWAY LIGHTING

Decorative or architectural roadway lighting is acceptable provided it meets the minimum design criteria and the objectives contained in this Manual. Examples include architectural lighting posts, cross arms, wall brackets, bollards, and light fixtures.

I ADAPTIVE LIGHTING

Some locations such as coastal roadways where sea turtles may be affected, may require lower lighting levels and different 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.

J OVERHEAD SIGN LIGHTING

If the visibility of the sign due to roadway geometry or retro reflectivity of the sign sheeting is inadequate, overhead sign lighting should be provided. 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. See ***Chapter 18 – Signing and Marking*** for signage retroreflectivity requirements.

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

Source: AASHTO Roadway Lighting Design Guide (October, 2005), Table 10 – 1 Illuminance and Luminance Levels for Sign Lighting.

*Based upon a maintained reflectance of 70 percent for white sign letters.

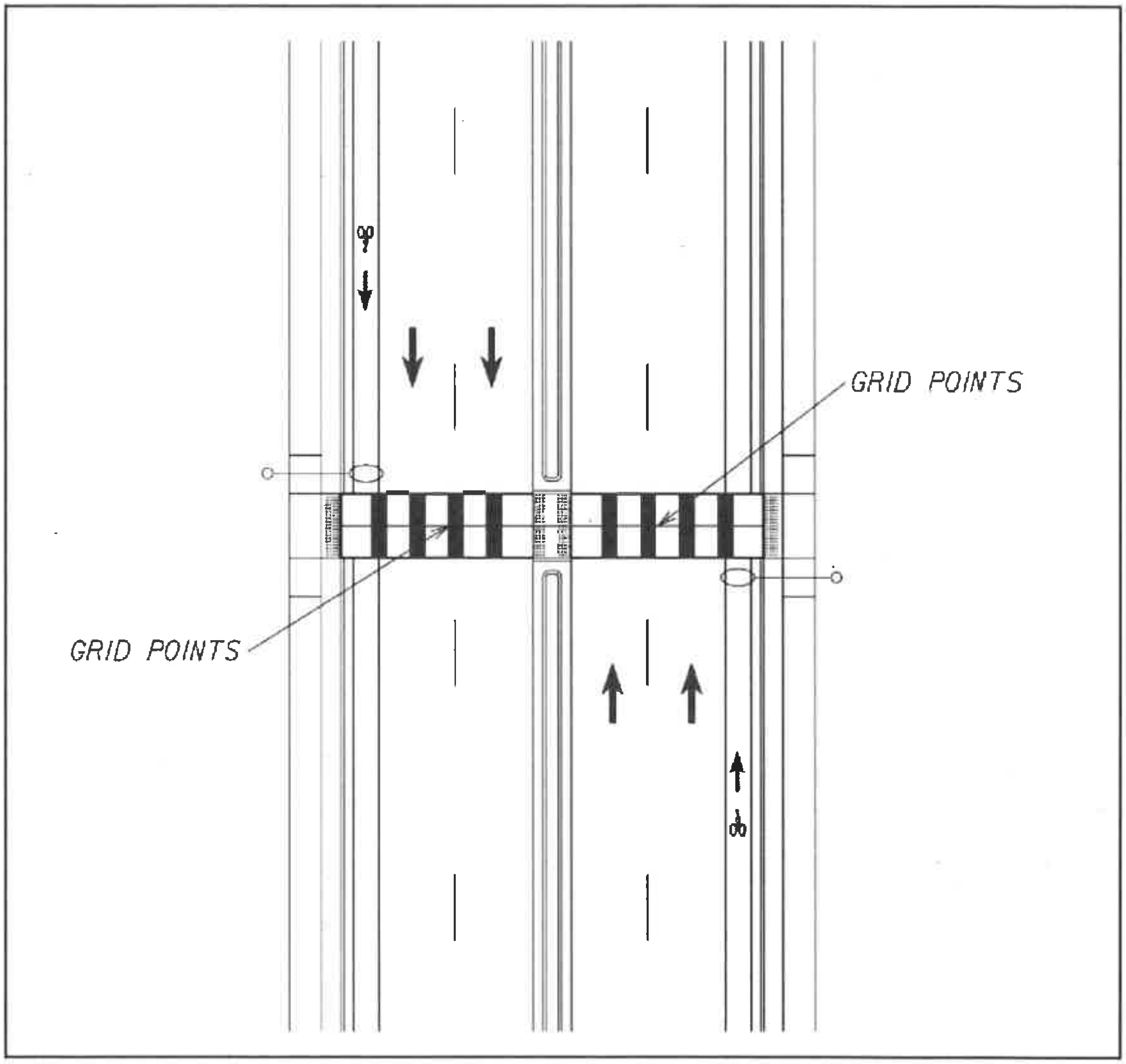
K ROUNDABOUTS

Roundabouts should be supplemented with roadway lighting. Where pedestrians are expected, provide additional lighting of 2.0-foot candles of maintained vertical illumination, measured at 5 feet from the road surface. Calculate the vertical illuminance for the crosswalk on each near side approach entering and exiting the roundabout.

L MIDBLOCK CROSSWALKS

At midblock pedestrian crossings, provide 2.0-foot candles of maintained vertical illumination, measured at 5 feet from the road surface. Calculate the vertical illuminance for the crosswalk on each near side approach.

Figure 6 – 2 Horizontal and Vertical Illuminance for Mid-Block Crosswalk



M 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***.

N 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 errant 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. In addition, the ***National Electrical Code (NEC)*** requires a working area for safety purposes around the poles. Further criteria regarding the placement of roadside structures, including light poles, is specified in ***Chapter 4 – Roadside Design***.

O 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
- Design Guide for Residential Street Lighting (2015), Illuminating Engineering Society
  https://www.ies.org/store/design-guides/design-guide-for-residential-street-lighting/
- 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
- The Lighting Handbook, 10th Edition, Illuminating Engineering Society (IESA)
  https://www.ies.org/store/lighting-handbooks/lighting-handbook-10th-edition/
- National Electric Code
  https://www.nfpa.org/NEC/About-the-NEC/Free-online-access-to-the-NEC-and-other-electrical-standards

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 Minimum 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

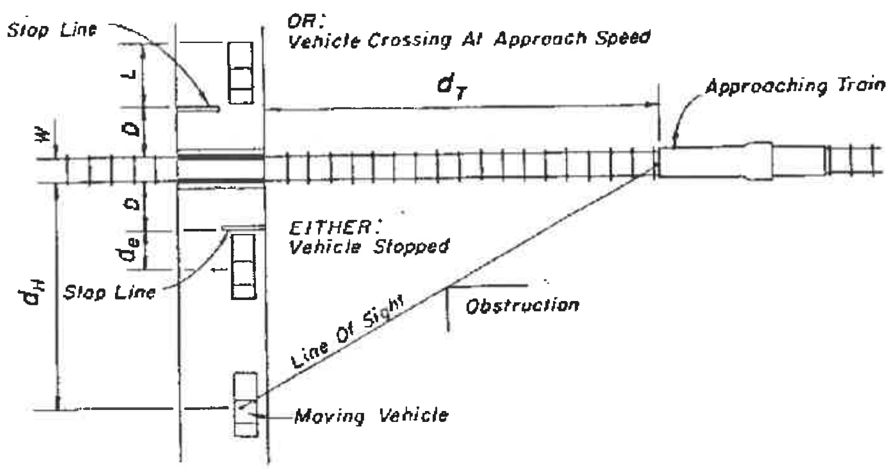
The sight distance required for a vehicle to cross a railroad from a stop is essentially the same as that required to cross a highway intersection as given in ***Chapter 3 – Geometric Design***.

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.

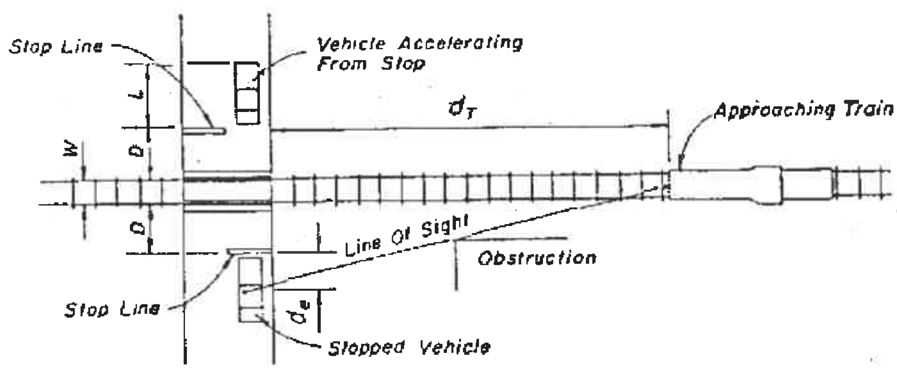
The setback for determining the required clear area for sight distance should be at least 10 feet more than the vehicle offset. Care should be exercised to ensure signal supports and other structures at the crossing do not block the view of drivers preparing to cross the tracks.

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 Table7-1.

Table 7 – 1 Sight Distance at Rail-Highway Grade Crossings

Design Sight Distances for Combinations of Train and Highway Vehicle Speeds Conditions:								
Single Track 90° Crossing Design Vehicle WB-62FL and WB-67 (L=73.5' d_e=8') Flat Highway Grades				Track Width (W) = 5' Vehicle Stop Position (D) = 15' 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) 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

(Continued on Next Page)

Table 7 – 1
Sight Distance at Rail-Highway Grade Crossings
(continued)

dH (feet) Sight Distance Along Highway							
	69	135	220	324	447	589	751

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)."***

Source: Developed from ***Table 9 – 32, A Policy on Geometric Design of Highway and Streets, AASHTO (2011).***

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.