

Section 1 - Introduction

1.1 Introduction

This manual presents the current Department guidelines pertaining to roadway design on the State Highway system (www.state.nj.us/transportation/refdata/sldiag/). It provides a means of developing uniformity and safety in the design of a highway system consistent with the needs of the motoring and non-motoring users.

Regarding controlling design elements (CDE's), it is recognized that situations occur where good engineering judgment will dictate deviation from the current Department design guidelines. Any such deviations from the design guidelines relative to the(CDE's) will require an approved design exception.

See the NJDOT Design Exception Manual for specific CDE's relative to the appropriate Type of Design Exception:

- Design Exception Type 1 (Design Speeds \geq 50 mph)
- Design Exception Type 2 (Design Speeds $<$ 50 mph)
- Design Exception Type 3 Major Access/Developer Projects (All Designs Speeds)

(Also refer to the Design Exception Manual for exemptions to the Design Exception Process.)

The guidelines contained in this manual, other than CDE's, are primarily informational or guidance in character and serve to assist the engineer in attaining good design. Deviations from this information or guidance do not require a design exception.

It is not the intent of this manual to reproduce all the information that is adequately covered by textbooks and other publications which are readily available to designers and technicians.

This manual, when used in conjunction with engineering knowledge of highway design and good judgment, should enable the designer to perform their job more efficiently.

The geometric design of streets and highways not on the State Highway system should conform to the standards as indicated in the current AASHTO – *A Policy on Geometric Design of Highways and Streets*. The design of traffic barriers and drainage systems shall conform to the *NJDOT Roadway Design Manual*.

1.2 Policy on Use of AASHTO Standards

The American Association of State Highway and Transportation Officials (AASHTO) has published policies on highway design practice. These are approved references to be used in conjunction with this manual. AASHTO policies represent nationwide standards that do not always satisfy New Jersey conditions. When standards differ, the instructions in this manual shall govern except on Interstate highways. The geometric design of the Interstate System, as a minimum, shall comply with the standards presented in the AASHTO publications; but the design of traffic barriers shall conform to the *NJDOT Roadway Design Manual*.

1.3 Reference Publications

- **Note: If there is a date given for the publication and a revised edition exists, use the current FHWA approved edition.**
- A. American Association of State Highway and Transportation Officials (AASHTO), American Association of State Highway Officials (AASHO)
- AASHTO – *A Policy on Geometric Design of Highways and Streets*, 2011
 - AASHTO – *A Policy on Design Standards - Interstate System*, 2005
 - AASHTO – *Roadside Design Guide*, 2011
 - AASHTO – *A Guide for the Development of Rest Areas on Major Arterials and Freeways*, 2001
 - AASHTO – *Guide for the Development of Bicycle Facilities*, 2012
 - AASHTO – *An Informational Guide for Roadway Lighting*, (1984)
 - AASHTO – *Guide for the Planning, Design and Operation of Pedestrian Facilities*, 2004
 - AASHO – *Highway Definitions*, 1968
 - AASHO – *A Policy on U-Turn Median Openings on Freeways*, 1960
- B. Transportation Research Board (TRB)
- TRB – *Highway Capacity Manual*, (2010)
- C. Federal Highway Administration (FHWA)
- FHWA – National Transportation Communications for ITS Protocol <http://www.ntcip.org/info/>
 - FHWA – Federal-Aid Policy Guide (FAPG), (1991 with Updates)
 - FHWA – Roundabouts: An Informational Guide, (2000), Publication No. FHWA-RD-00-067
 - FHWA – *Roadway Lighting Handbook*, (1978 and Addendums)
 - FHWA – Pedestrian Facilities Users Guide: Providing Safety and Mobility Publication No. FHWA-RD-01-102 (1999)
 - System Engineering Guidebook for ITS, (2007), <http://www.fhwa.dot.gov/cadiv/segb/>
 - FHWA – Manual on Uniform Traffic Control Devices, (2009)
- D. Institute of Transportation Engineers (ITE)
- ITE – *Alternative Treatments for At-Grade Pedestrian Crossings*, (2001)
- E. Illuminating Engineering Society North America (IESNA)
- IESNA – *Lighting Handbook*, 9th (2000)
- F. National Fire Protection Association
- *National Electrical Code (NEC)*, (2008)
 - *National Electrical Code (NEC) Handbook*, (2008)
- G. New Jersey Department of Transportation (NJDOT)
- NJDOT – *Bicycle Compatible Roadways and Bikeways: Planning and Design Guidelines*, (1996)
 - NJDOT – *Pedestrian Compatible Planning and Design Guidelines*, (1996)
 - *NJ Statewide ITS Architecture*, (2005)
 - *2017 State of New Jersey: Complete Streets Design Guide*
- H. National Committee on Uniform Traffic Laws and Ordinances (NCUTLO)

- NCUTLO – *Uniform Vehicle Code*, (2000)
- I. United States Access Board
 - ADA Access Board – *Recommendations for Accessibility Guidelines: Recreational Facilities and Outdoor Developed Areas*, (Published in the Federal Register July 23, 2004 and as amended through May 7, 2014)
- J. Department of Justice
 - 2010 Standards for Titles II and III Facilities: 2004 ADAAG.
- K. Public Rights-of-way Access Advisory Committee
 - Special Report: Accessible Public Rights-of-Way Planning and Design for Alterations (2007)
- L. Miscellaneous
 - Chicagoland Bicycle Federation BLOS/BCI Form – <http://rideillinois.org/advocacy/bikeped-level-of-service-measures-and-calculators/>
- Calculator for Bicycle Level of Service and Bicycle Compatibility Index

4.3 Horizontal Alignment

4.3.1 General

In the design of horizontal curves, it is necessary to establish the proper relationship between design speed, curvature and superelevation. Horizontal alignment must afford at least the minimum stopping sight distance for the design speed at all points on the roadway.

The major considerations in horizontal alignment design are: safety, grade, type of facility, design speed, topography and construction cost. In design, safety is always considered, either directly or indirectly. Topography controls both curve radius and design speed to a large extent. The design speed, in turn, controls sight distance, but sight distance must be considered concurrently with topography because it often demands a larger radius than the design speed. All these factors must be balanced to produce an alignment that is safe, economical, in harmony with the natural contour of the land and, at the same time, adequate for the design classification of the roadway or highway.

4.3.2 Superelevation

When a vehicle travels on a horizontal curve, it is forced radially outward by centrifugal force. This effect becomes more pronounced as the radius of the curve is shortened. This is counterbalanced by providing roadway superelevation and by the side friction between the vehicle tires and the surfacing. Safe travel at different speeds depends upon the radius of curvature, the side friction, and the rate of superelevation.

When the standard superelevation for a horizontal curve cannot be met, a design exception may be required. However, the highest practical superelevation should be selected for the horizontal curve design.

Figures 4-B, 4-C and 4-C1 give the design values for each rate of superelevation to be used for various design speeds and radii on mainline curves.

A 6 percent maximum superelevation rate shall be used on rural highways and rural or urban freeways (see Figure 4-B). A 4 percent maximum superelevation rate may be used on high speed urban highways to minimize conflicts with adjacent development and intersecting streets (see Figure 4-C). Low speed urban streets can use a 4 percent (See Figure 4-C) or 6 percent maximum superelevation rate (see Figure 4-C1)

Figure 4-C1 should be used in low speed built up areas. Although superelevation is advantageous for traffic operations, various factors often combine to make its use impractical in low-speed urban areas. These factors include:

- Wide pavement areas,
- The need to meet the grade of adjacent property,
- Surface drainage considerations,
- The desire to maintain low-speed operation, and
- Frequency of cross streets, alleys and driveways

Therefore, horizontal curves on low-speed urban streets are frequently designed without superelevation, sustaining the lateral force solely with side friction.

The 6 percent maximum superelevation rate for low speed urban streets allows for:

1. a higher threshold of driver discomfort than the 6 percent superelevation rate in Figure 4-B, and
2. application with sharper curvature than the 4 percent maximum superelevation rate in Figure 4-C.

In Figures 4-B, 4-C and 4-C1, Normal Crown (NC) is the traveled way cross section used on curves that are so flat that the elimination of adverse cross slope is not needed. Therefore the normal cross slope section can be used, which is a minimum 1.5 percent. Remove Adverse Crown (RC) are curves where the adverse cross slope should be eliminated by superelevating the entire roadway at the normal cross slope rate. RC is the minimum radii for a computed superelevation rate of 2.0 percent. For curve radii falling between NC and RC, a plane slope across the entire pavement equal to the normal cross slope should typically be used. A transition from the normal crown to a straight-line cross slope will be needed.

On flat radius curves requiring superelevation ranging from 1.5 percent to 2.0 percent, the superelevation should be increased by 0.5 percent in each successive pair of lanes on the low side of the superelevation when more than two lanes are superelevated in the same direction.

It may be appropriate to provide adverse crown (normal crown) on flat radius curves (less than 2 percent superelevation) to avoid water buildup on the low side of the superelevation when there are more than three lanes draining across the pavement. This design treatment would require a design exception where RC is required. Another option is to construct a permeable surface course or a high macotexture surface course since these surfaces appear to have the highest potential for reducing hydroplaning accidents. Also, grooving the pavement perpendicular to the traveled way may be considered as a corrective measure for severe localized hydroplaning problems.

Section 5 - Major Cross Section Elements

5.1 General

The major cross section elements considered in the design of streets and highways include the pavement surface type, cross slope, lane widths, shoulders, roadside or border, curbs, sidewalks, driveways, and medians. Due consideration should be given to the motoring and non-motoring users in designing the cross section.

5.2 Pavement

5.2.1 Surface Type

Pavement surface type is determined by soil conditions, traffic volume, traffic composition, material availability, initial cost, and the extent and cost of maintenance. All of these affect the relationship of cost to traffic service.

Generally, all roadways in the State are surfaced with hot mix asphalt materials or Portland cement concrete. These pavements provide good riding qualities, help to maintain the cross section, and adequately support the expected volume and weights of vehicles without failure due to fatigue. In considering cyclists and pedestrian traffic, other roadway surfaces include textured and colored asphalt, textured and colored concrete, and brick and other unit pavers. As part of urban design, landscape or streetscape treatments, these are used in crosswalks, bike lanes, shoulders, and traffic calming devices.

Important characteristics in relation to geometric design are the ability of a surface to sustain its shape and dimensions, the ability to drain, and the effect on driver, bicyclist, and pedestrian behavior.

5.2.2 Cross Slope

The cross slope of the pavement is the slope of the pavement surface measured transverse to the centerline of the highway. The high point of a normal cross slope of a roadway is known as the crown. Undivided pavements on tangents or on flat curves have a high point (crown) in the middle of the traveled way and slope downward toward both edges.

The minimum cross slope for concrete pavement and hot mix asphalt pavement should be 1.5 percent. The cross slope shall be uniform across the pavement section, from the high point to the edge of lane. The cross slope in each successive lane should be increased by 0.5 percent. However, it may be increased on each successive pair of lanes by 0.5 to 1 percent in order to cause the least disturbance to the existing border area, to limit the amount of resurfacing weight on a structure, or to minimize the cross slope in the outer lane when more than three lanes are sloped in the same direction.

In addition, if the cross slope of the left-turn lane is in the same direction as the adjacent lane, the adjacent lane cross slope may be used.

On a divided highway, each one way pavement may be crowned separately, as on a two lane highway, or it may have a unidirectional slope across the entire width of pavement, which is almost always downward to the outer edge.

A cross section where each roadway has a separate high point (crown) has an advantage of rapidly draining the pavement as shown in the top two drawings of Figure 5-A. In addition, the difference between high and low points in the cross section is kept to a minimum. The disadvantage is, additional drainage inlets and subsurface drainage lines are required. In addition, treatments of at grade intersections are more difficult because of the creation of several high and low points on the cross section. Preferably, use of such sections should be limited to regions of high rainfall. A cross section having no curbing and a wide depressed median are particularly well suited for high rainfall conditions.

Roadways that slope only in one direction provide more comfort to drivers because vehicles tend to be pulled in the same direction when changing lanes (As shown in the bottom four drawings of Figure 5-A). Roadways with a unidirectional slope may drain away from or toward the median. Providing drainage away from the median may affect a savings in drainage structures and simplify treatment of intersecting streets. Advantages of drainage toward the median are:

1. An economical drainage system, in that all surface runoff is collected into a single conduit.
2. Outer lanes, used by most traffic, are freer of surface water.

A major disadvantage of drainage toward the median is all the pavement drainage must pass over the inner, higher speed lanes. Where curbed medians exist, the drainage is concentrated next to and on higher speed lanes. This concentration of drainage, when the median is narrow, results in annoying and undesirable splashing onto the windshields of opposing traffic.

The rate of cross slope on curves as well as on tangent alignment is an important element in cross section design. See Section 4, "Basic Geometric Design Elements," for speed curvature relationships to determine pavement superelevation on curves.

5.3 Lane Widths

Lane widths have a great influence on driving safety and comfort. The predominant lane width on freeways and land service highways is 12 feet.

While lane widths of 12 feet are desirable on land service highways, circumstances may necessitate the use of lanes less than 12 feet. Lane widths of 11 feet in urban areas are acceptable. Existing lane widths of 10 feet have been provided in certain locations where right of way and existing development became stringent controls and where truck volumes were limited. However, new or reconstructed 10 foot wide lanes would not be proposed today, except in traffic calming areas.

On land service highways, where it is not practical to provide a shoulder adjacent to the outside lane, the outside lane width shall be 15 feet to accommodate bicyclists. Where alternate bike access is provided, the outside lane width should be 1 foot wider

than the adjacent through lane width. The designer should strive to accommodate the bicyclist and pedestrian on all projects.

When resurfacing existing highways that have lane widths of 10 feet or less, the existing lanes should be widened to either 11 foot minimum or 12 foot desirable.

Auxiliary lanes at intersections are often provided to facilitate traffic movements. Such lanes should be equal in width to the through lanes but not less than 10 foot wide when constructed adjacent to a shoulder. When there is no right shoulder adjacent to a new or reconstructed auxiliary lane, the width of the auxiliary lane shall be designed to accommodate the bicyclist. Where alternate bike access is provided, the auxiliary lane width should be 1 foot wider than the adjacent through lane width. The criteria in this paragraph shall also apply to auxiliary lanes at interchanges on land service highways.

On Interstates and freeways, the width of the auxiliary lane shall be 12 feet. Lane widths for specific types of highways are enumerated as part of the typical sections illustrated at the end of this section.

For the width of climbing lanes and left-turn lanes, see Section 4, "Basic Geometric Design Elements" and Section 6, "At-Grade Intersections," respectively.

5.4 Shoulders

5.4.1 General

A shoulder is the portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of subbase, base and surface courses.

Some of the more important advantages of providing shoulders are:

1. Space for the motorist to pull completely off the roadway for emergencies.
2. An escape zone to allow motorists to avoid potential accidents or reduce accident severity.
3. An aid to driver comforts by creating a sense of openness; improves highway capacity.
4. An improvement in sight distance in cut sections.
5. A provision to enhance lateral clearance for the placement of signs, guide rails, or other roadside appurtenances.
6. Space for pedestrians where there is no sidewalk and for bicycle usage.

New Jersey shoulder pavement design is based on the following engineering considerations.

- A. The New Jersey state highway system constitutes the heart of our state's surface transportation network. As a corridor state, the New Jersey highway system is subjected to the highest traffic count and loading in the nation.

- B. New Jersey highways continue to be faced with a serious backlog of deficient pavements in poor to fair condition. As such, many of the pavements are in the process of or will eventually be rehabilitated or reconstructed.
- C. Due to frequent traffic encroachment over the longitudinal joints next to the shoulder and the need to stage traffic on shoulders during rehabilitation, progressive shoulder deterioration will result if adequate shoulder pavement strength is not provided in the original construction.
- D. Shoulders of adequate pavement strength will carry traffic during the future construction of additional lanes, and the widening, resurfacing, rehabilitation and recycling of the existing lanes. The shoulders will also be used as an additional riding lane during peak hours relieving traffic congestion, such as in the case of "bus/shoulder" lanes.

The following shoulder pavement design policy is based on the above consideration. The term "Full Pavement Shoulder" is a shoulder pavement equal to that of the mainline pavement.

Full pavement shoulders shall be used as follows:

Full pavement shoulders shall be used for all new construction, reconstruction and widening on all portions of the NJ highway system.

For mainline pavement rehabilitation projects, shoulder pavement shall be designed to carry mainline traffic for a minimum period of 2 years or the following minimum section (whichever is greater):

2" Hot Mix Asphalt ___ Surface Course

3" Hot Mix Asphalt ___ Intermediate Course

8" Dense Graded Aggregate Base Course

5.4.2 Width of Shoulders

Desirably, a vehicle stopped on the right shoulder should clear the pavement edge by at least 1 foot, preferably by 2 feet. On land service highways, in difficult terrain, or in areas where right of way is restricted due to roadside development or environmental factors, a minimum 8 foot wide shoulder may be provided. On 3R projects, the existing shoulder width may be reduced to 8 feet to provide wider lanes. New or reconstructed shoulders on heavily traveled and high speed land service highways, especially those carrying large numbers of trucks (250 DHV), where turning volumes are high or dualization is anticipated, should have usable shoulders at least 10 feet and preferably 12 feet wide. Shoulders should be provided adjacent to all new acceleration and deceleration lanes at interchanges, where practical, in major new construction or reconstruction projects along major land service highways having an AADT of 10,500 per lane (DHV of 1,500 per lane) or greater, for the project design year. "Practical" is defined as given consideration to social, economic, and environmental impacts in concert with safe and overall efficient traffic operations.

Shoulder widths on freeways and Interstate highways shall be 10 feet minimum. However, where truck traffic exceeds 250 DDHV, a 12 foot shoulder should be