Roadway Geometric Design 5

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INTRODUCTION

This course is the **last** in a series of five volumes that summarizes and highlights the geometric design process for modern roads and highways. The course objective is to give engineers and designers an in-depth look at the principles to be considered when selecting and designing roads. Subjects covered include: *interchanges (types, warrants); and grade separated structures (overpasses, underpasses).* The contents of this document are intended to serve as guidance and not as an absolute standard or rule.

The *American Association of State Highway and Transportation Officials (AASHTO)* publishes and approves information on geometric roadway design for use by individual state transportation agencies. For this course, AASHTO's **A Policy on Geometric Design of Highways and Streets** (also known as the "Green Book") will be used primarily for fundamental geometric design principles. This text is considered to be the primary guidance for U.S. roadway geometric design.

The practice of geometric design will always be a dynamic process with a multitude of considerations: *driver age and abilities; vehicle fleet variety and types; construction costs; maintenance requirements; environmental sensitivity; land use; aesthetics; and most importantly, societal values.* Despite this dynamic character, the primary objective of good design will remain as it has always been – **to provide a safe, efficient and cost-effective roadway that addresses conflicting needs or concerns.**

INTERCHANGES

An interchange is a system of interconnecting roadways that uses grade separations and ramps to permit roadway traffic to pass through the junction without directly crossing any other traffic stream. The selection of the appropriate type of facility and its essential elements (freeway, cross streets, median, ramps and auxiliary lanes) are typically influenced by highway classification, traffic, design speed, and access control. Grade separation produces the greatest efficiency, safety, and capacity for intersecting traveled ways.

Interchange configurations can vary in shape or scope and range from single ramps to complex systems involving multiple highways. While the desired traffic operation should be the dominant design factor – aspects of topography, culture, and cost may also be major considerations.

Interchange Warrants

- Design designation
- Reduction of bottlenecks or spot congestion
- Reduction of crash frequency and severity
- Site topography
- Road-user benefits
- Traffic volume warrant

Grade separations may also be warranted where: local roads cannot be terminated outside the right-of-way; frontage roads or other access cannot be provided; a railroad-highway crossing may be eliminated; an unusual concentration of pedestrian traffic occurs; bikeways and pedestrian crossings are designated; access to mass transit stations is needed; and ramp free-flow operation is required.

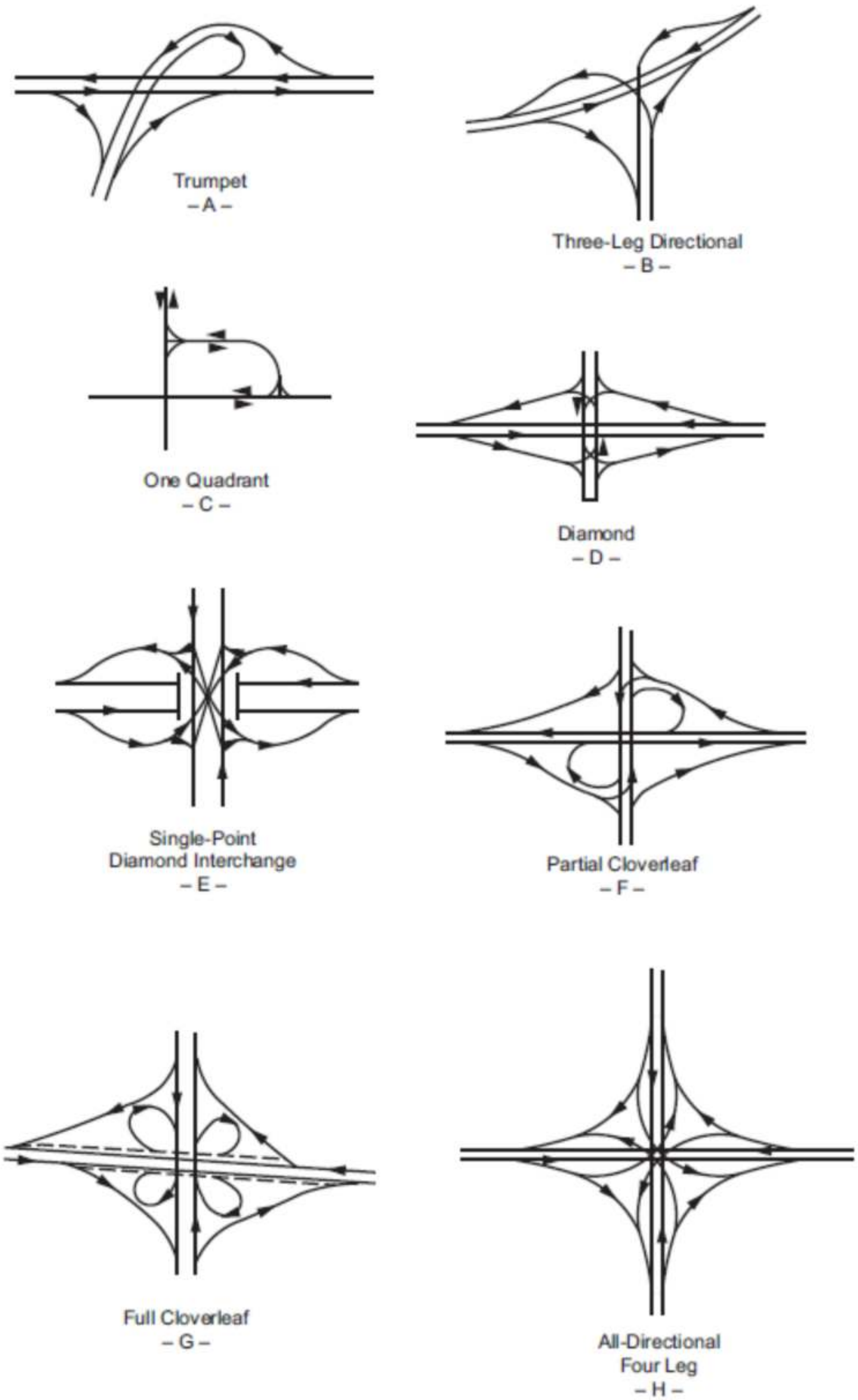


Figure 10-1. Interchange Configurations

Roadway interchanges are unique designs and are built to meet the specific needs at a certain location. Basic interchange configurations depend on: *topography; design controls; signage; culture; number of intersection legs; and expected traffic volumes*.

Interchange Configurations

System Interchange – connects 2 or more freeways

Service Interchange – connects freeways to lesser facilities

Rural interchange configurations are typically based on their service demand. Directional interchanges may be needed for intersecting freeways with high turning volumes.

Cloverleaf Interchange Minimum intersection design for 2 full-controlled access roads

Adaptable for rural locations with ample right-of-way and minimal weaving

Simple Diamond Interchange Most common for intersection of major road with minor facility

Capacity limited by at-grade ramp terminals at crossroads

Partial Cloverleaf Interchange Eliminates weaving of full cloverleaf design

Provides superior capacity

Appropriate where right-of-way is unavailable

Rural interchanges can be widely spaced and designed on an individual basis without impacting other interchanges. Final configurations may depend on available right-of-way, exit patterns, route continuity, advance exits, weaving, and signing. Sight distance should always be a major concern.

Urban interchanges should be considered as part of a system and not on an individual basis. Urban environments require considerable analysis of prevailing conditions. New interchange designs need to be both horizontally and vertically compatible with the urban corridor.

Interchange Design Principles

Weaving   Single exits in advance of structure   Potential for signing

Route continuity   Availability of right-of-way   Capacity   Cost
Potential for stage construction   Uniformity of exit patterns

Environmental compatibility

Design speeds, alignments, profiles and cross-sections for structure approaches should be consistent with the intersection. Grade separation geometry should exceed approaching roadway designs to reduce any sense of restriction. Interchange through highway alignments and profiles should be as flat and visible as practical.

Grade separation **sight distance** should meet or exceed stopping sight distance values. Decision sight distance is preferable where exits are involved, if practical. Above-minimum radii should be used for roadway horizontal curvature through interchanges.

The suggested **minimum interchange spacing** is 1 mile for urban areas and 2 miles for rural locations. Urban interchange spacing less than 1 mile may be used in conjunction with grade-separated ramps or collector-distributor roads.

Route continuity combines operational uniformity, proper lane balance, and maintaining a basic number of traffic lanes. This principle simplifies driving by providing a continuous through route – less lane changes, simpler signage, route delineation, and reduced driver distraction.

The **basic number of lanes** is the minimum number of lanes assigned to a freeway (regardless of changes in traffic volume or lane balance). The number of lanes is dependent on the traffic volume (DHV) over a significant length of roadway.

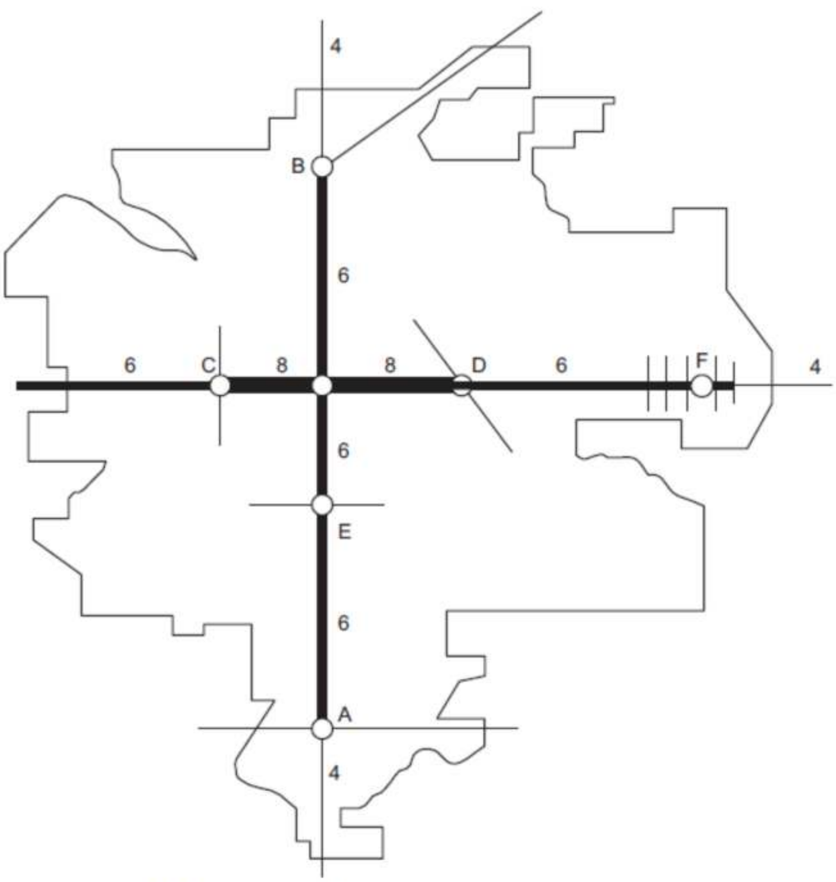


Figure 10-49. Schematic of Basic Number of Lanes

The number of lanes on the freeway and ramps should be balanced for efficient traffic operation through and beyond an intersection.

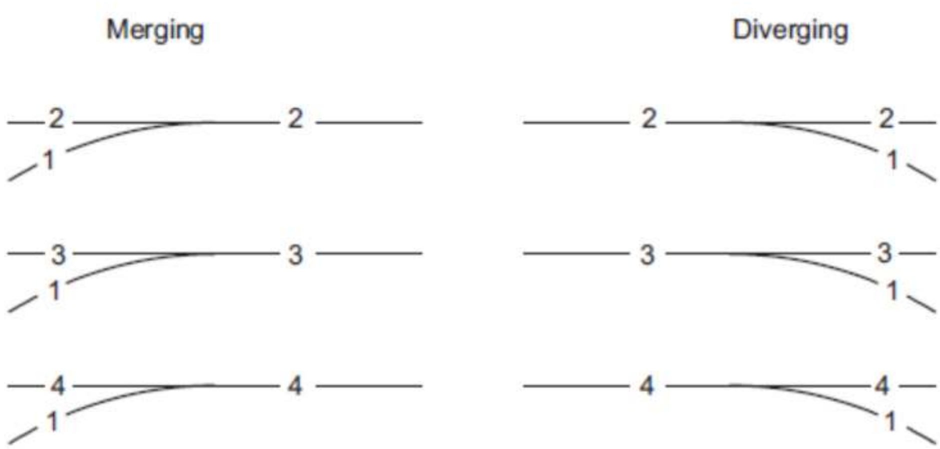
Lane Balance Principles

- For entrances – number of lanes beyond the merging of 2 traffic streams should equal to a minimum sum of all traffic lanes on the merging roadways minus one. This value may be equal to all traffic lanes on the merging roadways.

- For exits – number of highway approach lanes should equal the number of lanes beyond the exit plus the number of lanes on the exit minus one.
  Exceptions: *Cloverleaf loop-ramp exits that follow an entrance*

  Exits between closely spaced interchanges

- The highway traveled way should not be reduced by more than one traffic lane at a time.



Economics

Interchanges are the most expensive type of intersection – they are expensive to build and upgrade. The *initial costs* of the structure, ramps, through roads, grading, landscaping, utilities, and existing roadway modifications typically exceed those of a standard intersection. Interchange *maintenance costs* for slopes, lighting, signs, structure, and landscaping will also be more than those of other intersections. Any analysis of *vehicular operating costs* for interchanges is dependent on traffic, location, and design – making it difficult to compare to other intersection costs.

General Types of Grade-Separation Structures

- Deck-type (most common)
- Through
- Partial through

The best type of grade separated structure *appears* to provide a minimal sense of restriction to the driver. Designs that fit the existing topography (aesthetically and functionally) without distracting the motorist's attention elsewhere can provide excellent results. Driver behavior for structures where they pay little notice is similar to that at other highway locations.

Deck-type structures are most suitable for **overpasses**. Lower roadway supports may limit its lateral and vertical clearance – but are not visible for upper roadway motorists. The upper deck-type bridge has unlimited vertical clearance with lateral offset controlled by the protective barrier. Driver safety and the ability to redirect errant vehicles should take precedence over motorist viewing.

The most preferred type of **underpass** structure should span the entire roadway cross-section and provide an acceptable lateral offset of structural supports from the roadway. This offset should be flat and wide enough for vehicle recovery and to prevent motorist distraction.

An adequate number of cross streets should be grade-separated to preserve traffic flow continuing on local urban street systems – it is seldom economical to continue all cross streets across the main road. Currently, there is no limit or minimum spacing regarding the number of these cross streets (the number and location are governed by existing/planned local street systems).

Single Simple-Span Girder Bridge

Maximum Span: 150 feet

Accommodates severe skews & horizontal curves

Structure Depth: 1/15 to 1/30 of span

Two-span deck-type bridges are typically used for overpasses over divided highways. Continuous deck-girder type bridge (steel or concrete) with two or more spans provide savings in structure depth and deck joints.

Detailed studies may be used to help determine if a roadway should pass over or under the cross road. The best designs fit the existing topography – these are the most aesthetic and economic. If topography is not to be a governing factor, the following AASHTO guidelines should also be considered:

- Examine interchange alternatives as a whole when deciding if a major road overpasses or underpasses a cross road
- Undercrossings provide better driver visibility of approaching interchanges
- Ramp profiles work best where major roads are at the lower level for locations with significant turning traffic

- Major road overcrossings in rolling or rugged topography may be possible only by rolling grades or forced alignments
- Overpasses are the best alternatives for stage construction due to their minimum impact on the ultimate design
- Major highway crossovers can reduce possible drainage challenges by not altering underlying crossroad grades
- Bridge and approach costs may control where the major facility underpasses or overpasses minor roads and topography is not the primary concern
- Consider underpasses at locations where the major road can be constructed close to existing ground, on a continuous grade, and with no significant grade changes
- Overcrossings have no vertical clearance limits (advantageous for oversized loads)
- Roadways with the most traffic should have the fewest bridges (rideablity) and fewer conflicts (repairs)
- Depressed high volume facilities may be used to reduce noise
- Low volume overpasses can be used for economic reasons

Bridge widths should be as wide as practical to provide a sense of openness and continuity. Economy should not be the sole determinant for structure width – locations with wide shoulders, gutters, and flat slopes have fewer crashes. The ultimate width should result in a structure with balanced costs, usefulness or crash reduction.

Longitudinal Distance

Adequate longitudinal distances required for grade separation depend on:

design speeds

roadway gradients

rise or fall needed

For normal profile rise or falls of 25 feet or less needed for grade separation, the following should be avoided -

grades greater than 3% for 70 mph design speeds

grades greater than 4% for 60 mph design speeds

grades greater than 5% for 50 mph design speeds

grades greater than 6% for 40 mph design speeds

Flatter gradients than these values should generally be used for rise or fall values less than 25 feet.

The minimum distance required for a grade separation varies to a greater extent (for given gradients and profile rise/fall requirements) with changes in design speed.

Elevation differences of 20 to 22 feet are typically needed for grade separation (two roadways or railroad undercrossings) to ensure adequate vertical clearance and structure thickness. A difference of 28 feet is required at locations where a highway overcrosses a railroad. The profile rise or fall needed for grade separation may vary due to topography. For sites with limited available distances, it may be justified to reduce the proposed rise/fall by raising or lowering the intersecting road or railway.

UNDERPASSES

The type of underpass facility to use should be determined by the site's spatial, load, foundation, and general needs. While it is preferable to carry the entire roadway cross-section through the structure, conditions may require a reduction due to:

Structural design limitations

Vertical clearance issues

Grade controls

Crossing skews

Aesthetics

Costs

Cross-section widths at underpasses vary for two-lane or undivided multilane roadways and depend on functional classification and traffic volume.

Minimum **lateral offsets** (traveled way edge to protective barrier) are the normal shoulder width. The offset for the left side of each roadway on divided highways is determined by the median width.

	Minimum Median Width	Shoulder Width
4-Lane roadway	10 feet	4 feet
6 lanes or more	22 feet	10 feet

This minimum median width may be used to provide adequate shoulders and a rigid median barrier.

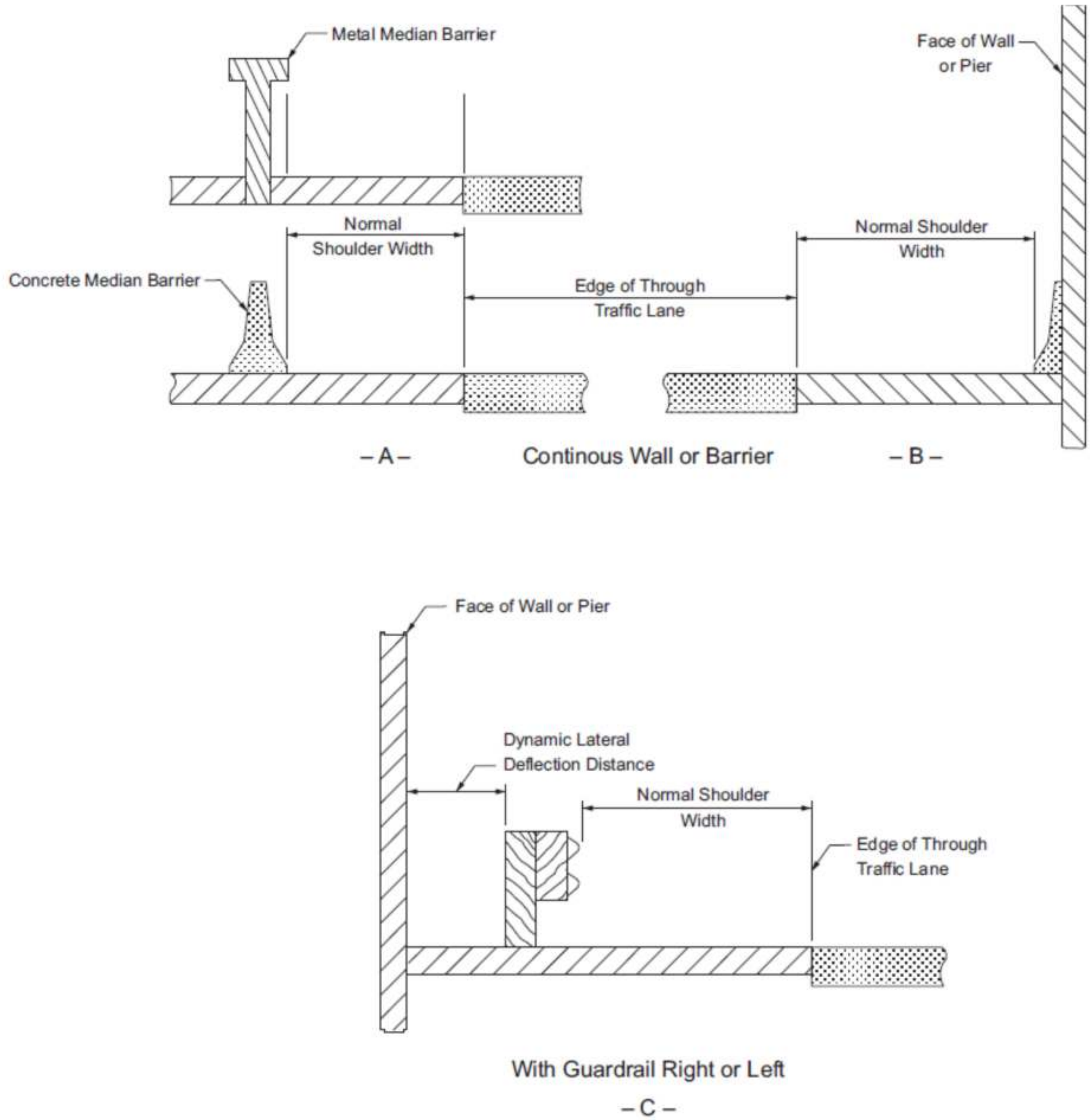


Figure 10-6. Lateral Offset for Major Roadway Underpasses

Most states allow vehicle heights (including load) to range from 13.5 to 14.5 feet. The **vertical clearance** for all structures needs to be a minimum of 1 foot greater than the legal vehicle height. A recommended minimum vertical clearance of 14.5 feet (desirable 16.5 ft) allows compensation for resurfacing, snow/ice, and overheight loads. The vertical clearance for depressed facilities restricted to passenger traffic should be 15 feet – not less than 12.5 feet.

OVERPASSES

Overpasses are typically deck structures and should have the same dimensional design as the roadway. These facilities are part of a continuous system that should contain consistent cross-section dimensions – unless cost prohibitive.

As with other structures, it is preferable to carry the roadway's full width across overpasses, if practical. If the design permits this, the parapet rail should line up with any guardrail on the approaching roadway. For locations where these offsets are different (agency specifics), transition rates of approximately 20:1 may be an appropriate taper connecting the longitudinal barrier to the bridge rail.

Auxiliary Lane	Lateral Offset to Bridge Rail
Ramp continuation	*Minimum width equal to approach ramp shoulder*
Weaving lane connector (entrance/exit ramps) or Parallel type speed change lanes	*Uniform width equal to ramp shoulder*

Overpasses for **divided** highways are typically built as two separate parallel structures with roadway widths carried across them. A raised median is desirable for bridges of 400 feet or more on **multilane, undivided** roadways. For bridges between 100 and 400 feet, other factors (traffic volumes, speed, sight distances, lighting, roadway cross-section) determine if medians are warranted.

AUXILIARY LANES

Auxiliary lanes adjoin through lanes to supplement traffic (turning, weaving, truck climbing, speed changes, storage, etc.) in order to balance traffic loads and maintain a uniform level of service. Auxiliary lanes aid vehicle position at exits and merging traffic at entrances. Lane widths should match those for through lanes.

Auxiliary lane designs start with a taper and can vary depending on location. Taper rates typically increase with speed – 8:1 for speeds up to 30 mph and 15:1 for maximum speeds of 50 mph. Urban taper lengths may be based on peak period speeds rather than the posted or design speeds.

A continuous auxiliary lane may improve operations between entrance and exit terminals at locations with:

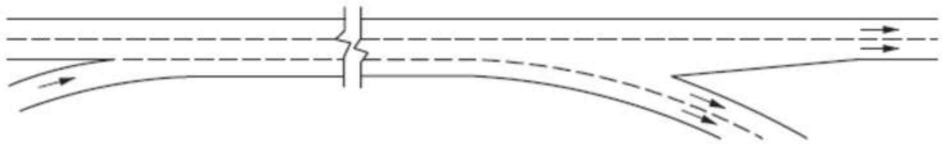
closely spaced interchanges

no local frontage roads

short distance between the entrance terminal taper end & exit terminal taper beginning

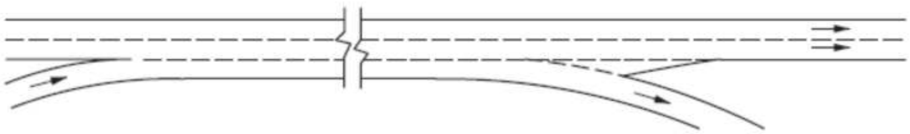
Auxiliary lanes may be used as single exclusive lanes or in combination with two-lane entrances.

Recovery lanes should be extended 500 to 1000 feet before tapering into through lanes – this distance can be increased to 1500 feet for larger interchanges.



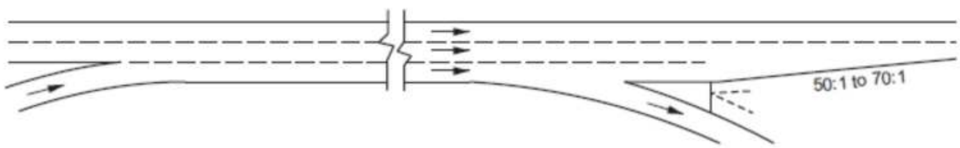
Auxiliary Lane Dropped on Exit Ramp

– A –



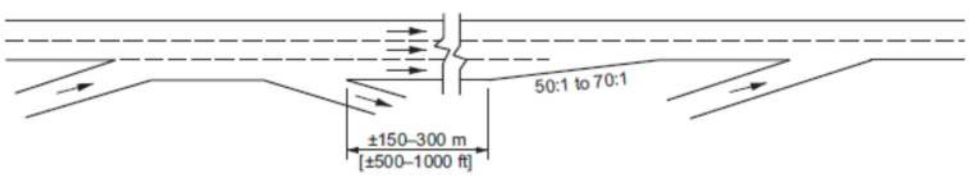
Auxiliary Lane between Cloverleaf Loops or Closely Spaced Interchanges Dropped on Single Exit Lane

– B –



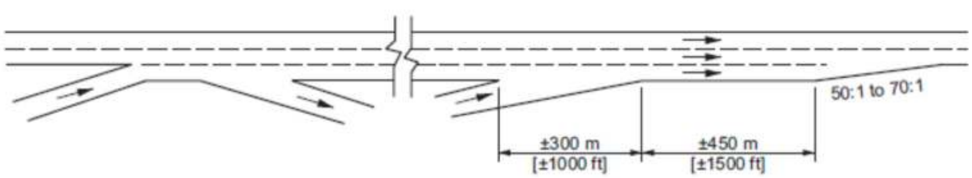
Auxiliary Lane Dropped at Physical Nose

– C –



Auxiliary Lane Dropped within an Interchange

– D –



Auxiliary Lane Dropped beyond an Interchange

– E –

Figure 10-52. Alternative Methods of Dropping Auxiliary Lanes

The basic number of lanes may be reduced beyond a principal interchange with a major fork or downstream from interchanges with another freeway. The basic number can also be reduced where a series of exits decrease the traffic load to justify a lower number of lanes. Lane drops can be made at two-lane exits or between interchanges.

THREE-LEG DESIGNS

Three-leg interchanges consist of one or more grade separations and one-way roads for traffic movements. These designs should be considered for locations where future development of the unused quadrant is unlikely – due to their difficulty to expand or modify. A **"T-interchange"** occurs when two intersection legs create a through road with an obtuse angle of intersection. A **"Y-interchange"** occurs if: all three legs have a through character; or the intersection angle is small (with the third leg).

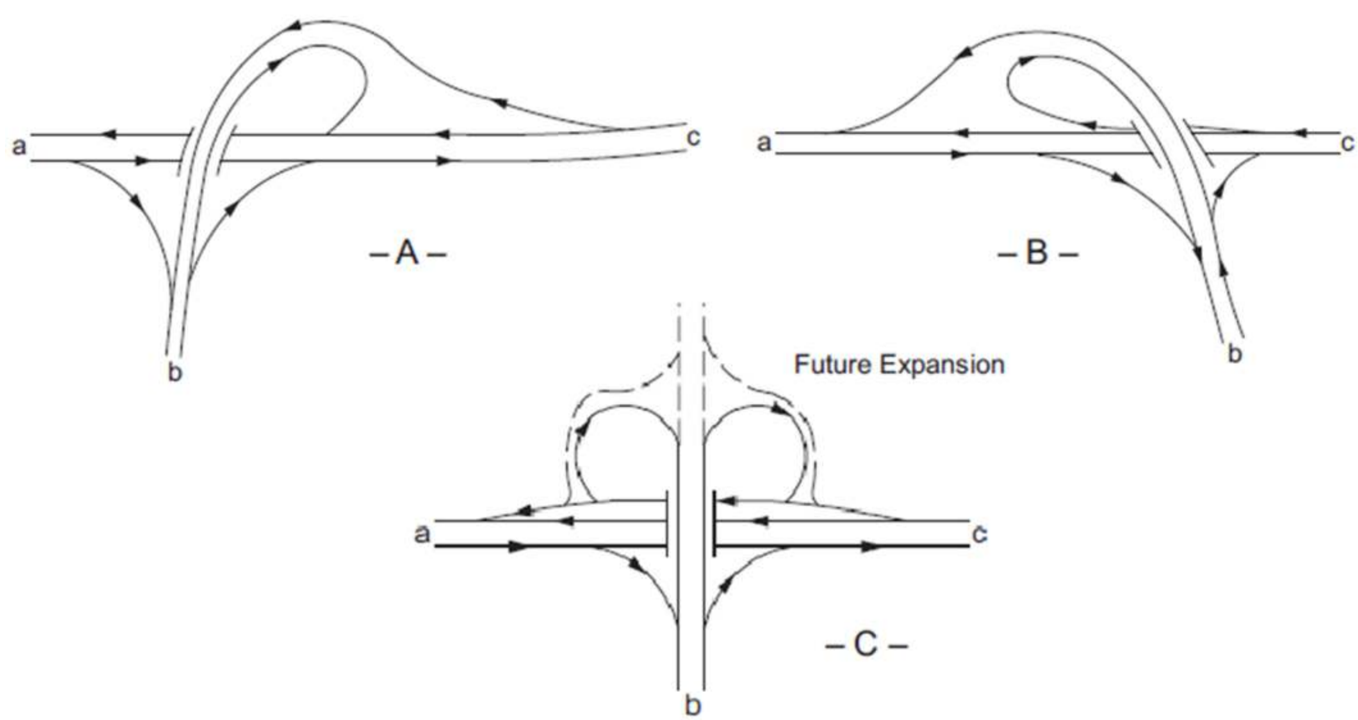


Figure 10-9. Three-Leg Interchanges with Single Structures

FOUR-LEG DESIGNS

Ramps in One Quadrant	Diamond Interchanges
Double Roundabouts	Single-Point Diamond Interchanges (SPDI)
Full or Partial Cloverleafs	Directional Interchanges

Interchanges that contain **ramps in a single quadrant** are suitable for low traffic locations. Simple "T-intersections" can be used for ramp terminals – single two-way ramps will normally be adequate for all turning traffic. Extensive channelization may be required at ramp terminals, medians and left-turn lanes to control turning movements for ramps in one quadrant. This type of interchange may be one phase of a stage-constructed project with the ramps designed for the ultimate development.

Diamond interchanges are considered to be one of the most common four-leg designs. Full-diamonds contain one-way diagonal ramps in each quadrant. These interchanges have both urban and rural applications – particularly for major-minor crossings with left minor road turns. Crossroad medians should be used to facilitate channelization and prevent wrong-way entry. Moderate to high cross street traffic locations typically need signalization. Interchange left-turning movements normally require multiphase control. Interchange designs with frontage roads may act as part of a series – with ramps connecting to the frontage road at a minimum of 350 feet from the crossroad.

Double roundabout interchanges are diamond designs with roundabouts at each ramp terminal. This type of interchange eliminates any signal control while providing a narrower bridge footprint (no storage lanes). The roundabouts take care of arterial left and right turns as well as all cross street movements. Approaching profile grades to the roundabouts should not exceed 3 percent (anything over 4% can restrict sight distance).

Single-point diamond interchanges (SPDI) or *single-point urban interchanges (SPUI)* control all four turning movements by a sole traffic signal with opposing left turns operating to the left of each other. SPDI's normally contain narrow right-of-way, high costs, and greater diamond capacities. These are suitable for urban locations with restricted right-of-way but may be used at other sites with environmental, geographical or other constraints. Left turn angles (45 to 60 degrees) and curve radii (150 to 200 feet minimum) are flatter than typical intersections which enable higher speeds and higher capacities.

Overpass Type	Length
Single-span	220 feet (typically)
Three-span	400 feet or more

Cloverleaf designs use loop ramps for left-turning traffic. Full cloverleafs contain loops in all four interchange quadrants; Partial cloverleafs refer to all others. These designs are better suited for suburban/rural areas with available space and are more expensive than diamond designs. Increased speed is a major advantage while increased travel time, distance, and required right-of-way are some disadvantages. The recommended radii for loops on minor highway movements range from **100 to 170 feet** for maximum design speeds of 50 mph – with 150 to 250 feet for important highway movements with high design speeds.

Partial Cloverleaf Ramp Guidelines

- Ramp systems need to enable major turns by right-turn exits/entrances
- Locations with high through-traffic volumes on major highways greater than minor roads – right turn ramps are preferred on the major road

Direct connection: Ramp that does not substantially deviate from the intended direction of travel

Semidirect connection: Ramp that veers to the right away from the intended direction of travel, gradually reverses, and passes other interchange ramps before entering the other road

Directional interchanges are typically used for intersection locations containing two high-volume freeways. These types of interchanges contain only direct or semidirect connections from one freeway to the other – at-grade intersections are eliminated. Each directional interchange is a unique design based on traffic, cost, environmental concerns, etc. which require detailed studies and alternative generation. Common configurations fit site locations, accommodate vehicle traffic, limit weaving, minimize complex structures, and fill the least space.

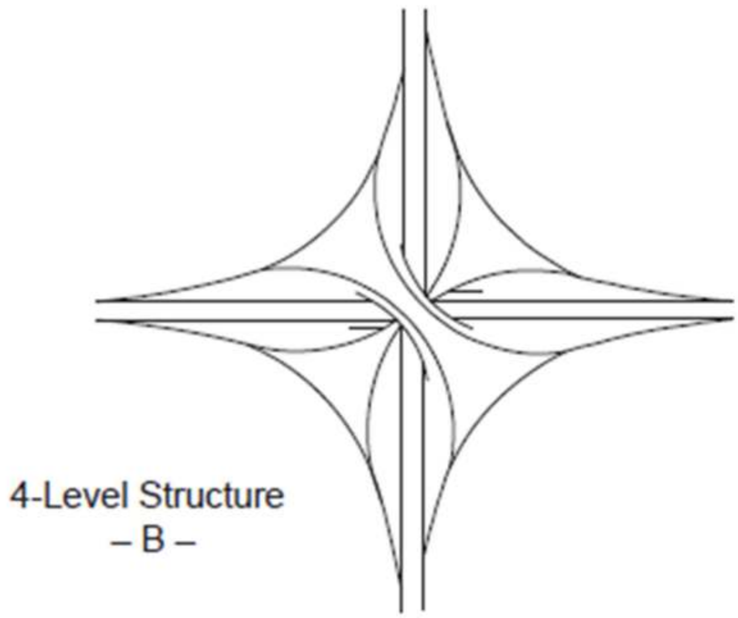


Figure 10-34. Directional Interchanges With Multilevel Structures

Advantages of Directional Interchanges

Preferred for two high-volume freeway intersections

Reduces travel distances

Increases speed and capacity

Eliminates weaving

Avoids out-of-direction travel on loops

Disadvantages of Directional Interchanges

More expensive due to number of ramps/bridges

Right-of-way needed

Required studies and alternative generation

RAMPS

Ramps are turning roadways used for connecting multiple legs at an interchange. Each ramp contains a terminal for each interchange leg and a connector road (typically involving curves and grades). Ramps are normally one-way facilities.

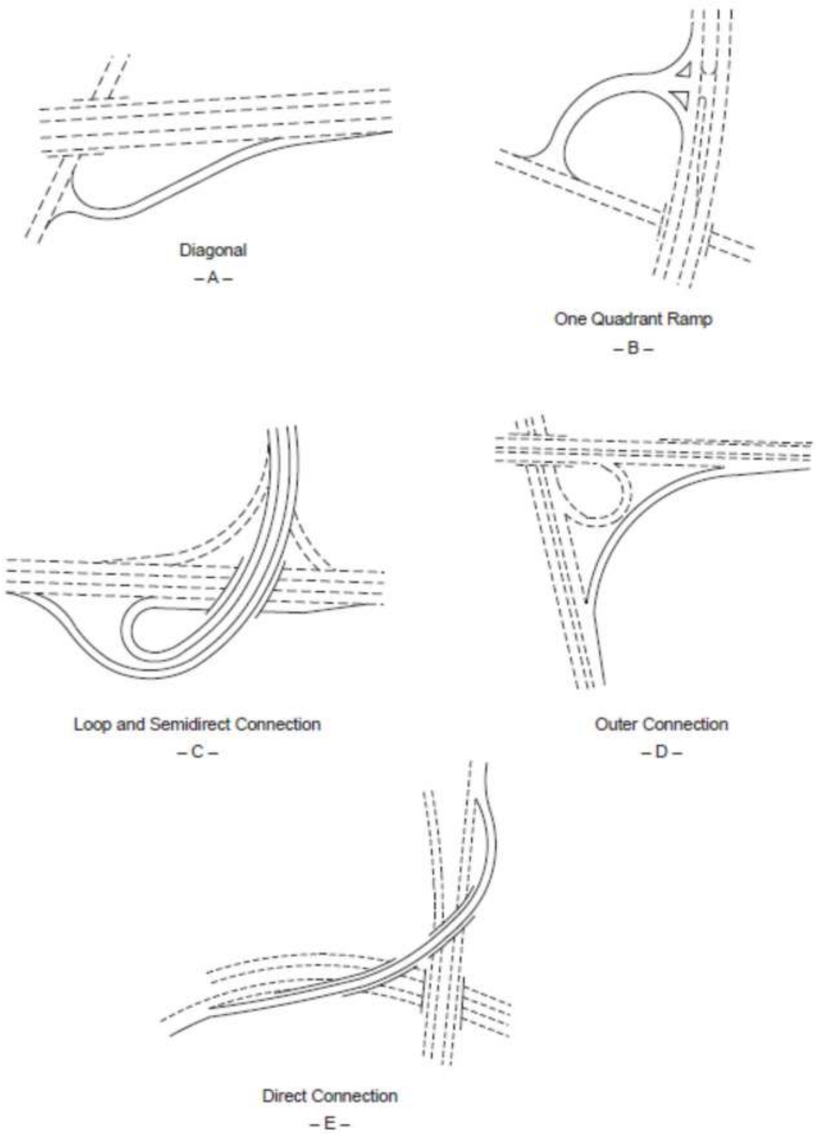


Figure 10-58. General Types of Ramps

Diagonal ramps are usually tangent or wishbone-shaped with a reverse curve. These may have both right and left turning movements at the minor road intersection terminal.

Loop ramps can contain single turn movements (left or right) or double turning movements (left and right) at their termini. This ramp type usually has longer indirect travel distances than any other.

Semidirect connections (jughandles) involve exiting on the right, headway away, gradually reversing, passing other ramps, and entering the other road. These are typically used where conventional diagonal ramps are inappropriate. Travel distances are less than loop ramps but more than direct connections.

General Ramp Design Considerations

Design speed should mimic low-volume speeds for intersecting highways, if practical. The highway with the greater design speed should control the speed for the entire ramp facility. Lower speeds may be used but not less than the lower ranges shown below. Speeds of 50 mph or more apply to freeway/expressway exits. The table values address the controlling ramp curvature and not the ramp terminals. These terminals should be transitioned with speed-change facilities for the highway speeds.

Table 10-1. Guide Values for Ramp Design Speed as Related to Highway Design Speed

U.S. Customary										
Highway design speed (mph)	30	35	40	45	50	55	60	65	70	75
Ramp design speed (mph)										
Upper range (85%)	25	30	35	40	45	48	50	55	60	65
Middle range (70%)	20	25	30	33	35	40	45	45	50	55
Lower range (50%)	15	18	20	23	25	28	30	30	35	40
Corresponding minimum radius (ft)	see Table 3-7									

Loop ramp design speeds are typically limited to minimum values. For highway design speeds above 50 mph, the minimum loop design speed should be 25 mph. Ramps speeds over 30 mph generally require significant land areas that can be unavailable in urban locations.

Two-lane loop ramps may be needed for developing or high-traffic areas. The addition of a loop ramp before or after a two-lane loop should be avoided. The minimum radius for the loop ramp's inner edge of traveled way should be 180 to 200 feet.

Semidirect connections should use middle and upper values for design speed – typically 30 to 40 mph. Speeds less than 30 mph should be avoided – with 50 mph or greater speeds inappropriate for short single-lane ramps.

Direct connections use middle to upper design speed values with minimum design speeds of 40 mph.

Curvature

Curve transitions (compound or spiral) benefits include:

Desired ramp alignment

Comfortable design speed transitions (through and turn sections)

Natural vehicle path fit

Any unexpected or abrupt speed changes should be avoided.

Ramp Curvature Factors

Traffic pattern

Design speed

Traffic volumes

Topography

Culture

Intersection angle

Ramp termini

The preferred design for an outer connection ramp is one with a continuous curve. This alignment may require extensive right-of-way. Another popular alignment involves a central tangent with terminal curves.

Diagonal ramp shapes depend on traffic patterns and right-of-way limitations. Slip ramps are a variation of diagonal ramps that connect with parallel frontage roads (preferably one-way frontage roads).

Sight Distance

Sight distances for ramps should meet or exceed those for stopping sight distance. The entire exit terminal should be visible – including exit nose and the roadway past the gore area. Sight distance for areas preceding the exit ramp approach nose should exceed the minimum stopping sight distance for through traffic – preferably by a minimum of 25 percent.

Vertical Grades

Ramp grades should be designed to minimize the driving effort needed to switch roadways – flat as practical. Due to typical ramp lengths (400 to 1200 feet), ramp gradients may need to be steeper than those of the intersecting roadway. While the grade is dependent on factors specific to its location, the flatter the ramp gradient → the longer.

Short upgrades of 7 to 8 percent operate adequately without significantly slowing down traffic. Upgrades of 5 percent do not negatively impact bus and truck operations. Downward gradients of 8 percent do not necessarily produce undue results from excessive passenger vehicle acceleration – there is a greater potential for increased heavy vehicle speeds. For locations with sharp horizontal curves and heavy truck/bus traffic, downward grades should be limited to 3 or 4 percent (desirable).

Although design speed is not directly related to ramp grades, it is an indicator of the design quality. High speed grades should be flatter than those for low speeds. Ramp alignments and grades should be jointly coordinated.

Desirable General Criteria

Design Speed	Gradient*
45 to 50 mph	3 – 5%
40 mph	4 – 6%
25 to 30 mph	5 – 7%
15 to 25 mph	6 – 8%

*Downgrades may be 2% greater for special causes

Ramp Length Factors

- Intersection angles of 70° or less
  Ramp may be moved farther away to provide sufficient length for satisfactory grades
- Intersection legs with significant grades having an upper ascending road and a lower descending road
  Ramp will achieve a large elevation difference that increases with distance from the facility
- Ramps that leave the lower road (downgrade) and meets the higher road (downgrade)
  Longer than normal terminal vertical curves may require long ramps to meet grade limits

Ramp Cross-slope Guidelines

- Ramp cross-slopes on tangent sections should be sloped 1.5 to 2 percent one way.
- Superelevation runoff rate of changes should be based on the maximum relative gradient.

- The crossover crown line at the edge of the through-traffic lane is an important control for developing ramp terminal superelevation.
- The exit terminal, ramp proper, and entrance terminal should be analyzed in combination to determine superelevation rates.

Diamond ramps typically contain a high-speed exit, tangent/curved alignment, and stop/yield entrance conditions. Deceleration should occur on the exit terminal's auxiliary lane and continue to the stop/yield on the ramp proper. The superelevation and radii should reflect decreasing speeds for the exit, ramp, and entrance.

Loop ramps are made up of moderate-speed exit terminals, slow-speed ramp sections, and moderate-speed acceleration lanes. Ramp curvature may be a simple curve or a combination determined by the design speed and superelevation rate.

Direct and **semi-direct** ramps usually consist of a high-speed exit, moderate/high-speed ramp proper, and a high-speed entrance – resulting design speeds and superelevation rates similar to those for open-roads.

Gore Areas

Gores are defined by AASHTO as "an area downstream from the shoulder intersection points". The *physical nose* is upstream of the gore and separates the roadways. The *painted nose* is the actual point of separation. The *neutral area* is the triangular area between the painted and gore noses. These areas are a crucial part of exit ramp design that should be highly visible and understood.

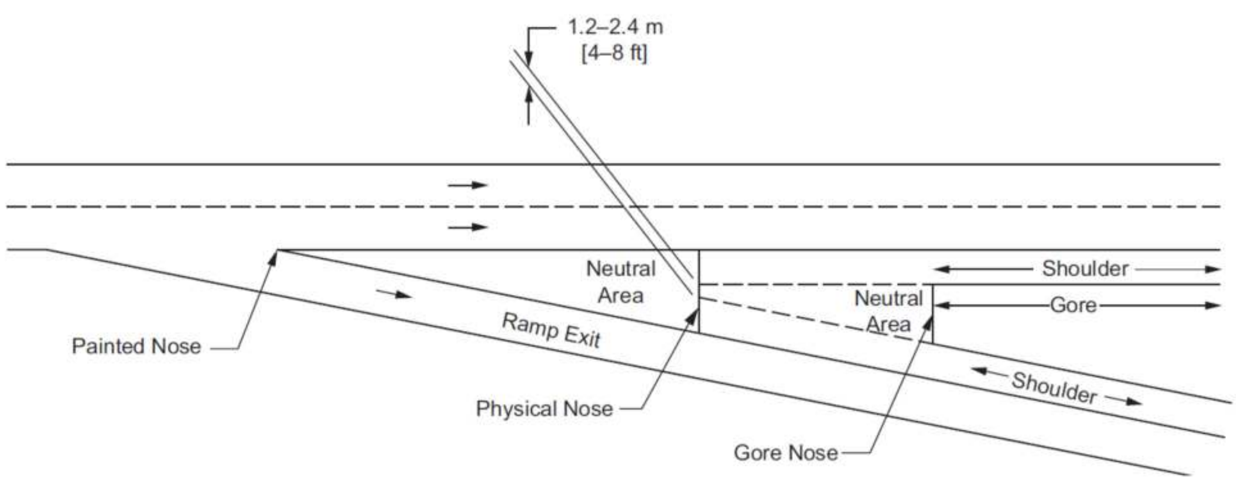


Figure 10-61. Typical Exit Gore Area Characteristics

Gore nose widths are typically 20 to 30 feet which includes paved shoulders – measured between the mainline traveled way and that of the ramp. This width may be increased for locations where the ramp curves away immediately beyond the gore nose or for expected speeds over 60 mph.

The neutral area should be properly marked (striping) to define proper travel paths and assist driver operation. Raised pavement markers can also be used for delineation. Any supplemental devices (rumble strips, etc.) should be placed where drivers have adequate reaction times.

Gores may also be used for entrance ramps. The point of convergence at the paved area is referred to as the *merging end*. The triangular maneuver area and layout is similar to those for an exit with less decision emphasis. The base width of the paved triangle is typically limited to the sum of the shoulder widths for the ramp and highway plus the physical nose (4 to 8 feet).

Traveled-Way

Traveled –way widths for ramps are determined by their operation, curvature, and traffic. Roadway widths (turning roadway) consist of the traveled-way plus the shoulder or equivalent offset. AASHTO Table 3-29 shows values for the three major traffic design conditions – **A, B and C**.

Table 3-29. Design Widths of Pavements for Turning Roadways

Metric

Radius on Inner Edge of Pavement, *R* (m)	Pavement Width (m)								
	Case I One-Lane, One-Way Operation—no provision for passing stalled vehicle			Case II One-Lane, One-Way Operation—with provision for passing stalled vehicle			Case III Two-Lane Operation—either one-way or two-way operation		
	Design Traffic Conditions								
	A	B	C	A	B	C	A	B	C
15	5.4	5.5	7.0	6.0	7.8	9.2	9.4	11.0	13.6
25	4.8	5.0	5.8	5.6	6.9	7.9	8.6	9.7	11.1
30	4.5	4.9	5.5	5.5	6.7	7.6	8.4	9.4	10.6
50	4.2	4.6	5.0	5.3	6.3	7.0	7.9	8.8	9.5
75	3.9	4.5	4.8	5.2	6.1	6.7	7.7	8.5	8.9
100	3.9	4.5	4.8	5.2	5.9	6.5	7.6	8.3	8.7
125	3.9	4.5	4.8	5.1	5.9	6.4	7.6	8.2	8.5
150	3.6	4.5	4.5	5.1	5.8	6.4	7.5	8.2	8.4
Tangent	3.6	4.2	4.2	5.0	5.5	6.1	7.3	7.9	7.9

Width Modification for Edge Conditions			
No stabilized shoulder	None	None	None
Sloping curb	None	None	None
Vertical curb:			
one side	Add 0.3 m	None	Add 0.3 m
two sides	Add 0.6 m	Add 0.3 m	Add 0.6 m
Stabilized shoulder, one or both sides	Lane width for conditions B & C on tangent may be reduced to 3.6 m where shoulder is 1.2 m or wider	Deduct shoulder width(s); minimum pavement width as under Case I	Deduct 0.6 m where shoulder is 1.2 m or wider

Note:

A = predominantly P vehicles, but some consideration for SU trucks

B = sufficient SU-9 vehicles to govern design, but some consideration for semitrailer combination trucks

C = sufficient bus and combination-trucks to govern design

U.S. Customary

Radius on Inner Edge of Pavement, *R* (ft)	Pavement Width (ft)								
	Case I One-Lane, One-Way Operation—no provision for passing stalled vehicle			Case II One-Lane, One-Way Operation—with provision for passing stalled vehicle			Case III Two-Lane Operation—either one-way or two-way operation		
	Design Traffic Conditions								
	A	B	C	A	B	C	A	B	C
50	18	18	23	20	26	30	31	36	45
75	16	17	20	19	23	27	29	33	38
100	15	16	18	18	22	25	28	31	35
150	14	15	17	18	21	23	26	29	32
200	13	15	16	17	20	22	26	28	30
300	13	15	15	17	20	22	25	28	29
400	13	15	15	17	19	21	25	27	28
500	12	15	15	17	19	21	25	27	28
Tangent	12	14	14	17	18	20	24	26	26

Width Modification for Edge Conditions			
No stabilized shoulder	None	None	None
Sloping curb	None	None	None
Vertical curb:			
one side	Add 1 ft	None	Add 1 ft
two sides	Add 2 ft	Add 1 ft	Add 2 ft
Stabilized shoulder, one or both sides	Lane width for conditions B & C on tangent may be reduced to 12 ft where shoulder is 4 ft or wider	Deduct shoulder width(s); minimum pavement width as under Case I	Deduct 2 ft where shoulder is 4 ft or wider

Note:

A = predominantly P vehicles, but some consideration for SU trucks

B = sufficient SU-30 vehicles to govern design, but some consideration for semitrailer combination trucks

C = sufficient bus and combination-trucks to govern design

SUMMARY

This course is the **last** in a series of five volumes that summarizes and highlights the geometric design process for modern roads and highways. The objective of this series was to give engineers and designers an in-depth look at the principles to be considered when selecting and designing roads.

The *American Association of State Highway and Transportation Officials (AASHTO)* publishes and approves various information on geometric roadway design for use by individual state transportation agencies. The majority of today's geometric design research is sponsored and directed by AASHTO and the Federal Highway Administration (FHWA) through the National Cooperative Highway Research Program (NCHRP).

AASHTO's **A Policy on Geometric Design of Highways and Streets** (also known as the "Green Book") is considered to be the primary guidance for U.S. roadway geometric design and was used throughout this series for its fundamental geometric design principles.

This document is intended to explain some principles of good roadway design and show the potential trade-offs that the designer may have to face in a variety of situations. The practice of geometric design will always be a dynamic process with a multitude of considerations. Despite this dynamic character, the primary objective of good design will remain as it has always been – **to provide a safe, efficient and cost-effective roadway that addresses conflicting needs or concerns.**

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