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Roadway Cross-Sections II

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INTRODUCTION

The AASHTO "Green Book" defines a **roadway cross-section** as *"a vertical section of the ground and roadway at right angles to the centerline of the roadway, including all elements of a highway or street from right-of-way line".* Along with the vertical alignment (grades and vertical curves) and horizontal alignment (tangents and curves), the roadway cross-section (lanes and shoulders, curbs, medians, roadside slopes and ditches, sidewalks) helps to present a three-dimensional roadway model. Its ultimate goal is to provide a safe, smooth-flowing facility that is crash-free.

This course is the second of two in this series that focuses on the geometric design of cross-sections for modern roads and highways. Its contents are intended to serve as guidance and not as an absolute standard or rule.

Upon course completion, you should be familiar with the general design concepts for roadway cross-sections. The course objective is to give engineers and designers an in-depth look at the principles to be considered when selecting and designing a roadway.

Subjects covered include:

Medians
Frontage roads
Outer separations
Noise control
Roadside control
Tunnels
Pedestrian facilities
Bicycle facilities
Bus turnouts
On-street parking

A Policy on Geometric Design of Highways and Streets (also known as the "Green Book") published by the *American Association of State Highway and Transportation Officials (AASHTO)* is considered to be the primary guidance for U.S. roadway design. For this course, **Chapter 4 - Cross-Section Elements (Sections 4.11 through 4.20)** will be used exclusively for fundamental roadway geometric design principles.

BACKGROUND

Roadway geometric design consists of the following fundamental three-dimensional features:

Vertical alignment - grades and vertical curves (“profile”)

Horizontal alignment - tangents and horizontal curves (“centerline”)

Cross section - lanes and shoulders, curbs, medians, roadside slopes and ditches, sidewalks

Combined, these elements contribute to the roadway’s operational quality and safety by striving to provide a smooth-flowing, crash-free facility. Roadway geometric design will always be a dynamic process with a multitude of considerations, such as

driver age and abilities
vehicle fleet variety and types
construction costs
maintenance requirements
environmental sensitivity
land use
aesthetics

and most importantly *societal values.*

Engineers must understand how all of the roadway elements contribute to overall safety and operation. Applying design standards and criteria to ‘solve’ a problem is not enough.

The fundamental objective of good geometric design will remain as it has always been **– to produce a roadway that is safe, efficient, reasonably economic and sensitive to conflicting concerns.**

MEDIANS

Roadway medians separate opposing lanes of traffic and are suitable for multilane arterials. This area is located between the edges of opposing traveled ways (including any left shoulders). Median width and design characteristics are among the most important safety features of high-speed highways in both urban and rural areas.

Principal Median Functions

- Separate opposing traffic
- Provide clear recovery area (errant vehicles)
- Provide emergency stopping areas
- Allow space for speed changes
- Provide storage for left-turns and U-turns
- Lessen headlight glare
- Provide space for future widths

Medians need to be highly visible regardless of time of day and should contrast with the traveled way to ensure maximum efficiency. Benefits of medians include: providing an open green space; offering a pedestrian refuge area; and controlling intersection traffic conflicts.

Median widths are dependent on the roadway type and location. Any proposed median widths should be evaluated for potential barrier needs. Ideally, median widths (typically 4 to 80 feet) should be sufficient so that no barrier is needed, when practical. The wider medians are safer but more costly - requiring more right-of-way, construction, and maintenance. These costs often limit median widths – costs increase as median widths increase.

In rural areas, medians are normally wider than in urban and suburban areas. Medians at unsignalized intersections need to be wide enough for selected design vehicle crossroad and U-turn traffic. In urban and suburban areas, narrow medians work better operationally – wide medians being used only if large vehicles are anticipated. Wide medians may not be suitable for signalized intersections due to the increased time for crossing vehicles and leading to inefficient signal operation.

Depressed medians (with typical sideslopes of 1V:6H) are normally used for freeways due to drainage efficiency. Any drainage inlets need to be flush with the ground. Culvert ends should have traversable safety grates.

Raised medians are generally used to regulate turning movements on arterials. This area is frequently used for landscaping and plants/trees. It is vital to prevent these from becoming visual obstructions and impacts to sight distance. Please consult the *AASHTO Roadside Design Guide* when designing for planting and/or landscaping within median areas.

Flush medians are typically crowned (to eliminate ponding) and used on urban arterials. This type of median can be used on freeways but may require some type of median barrier. Slightly depressed medians with steepened roadway cross slopes (approximately 4 percent) are generally preferred.

Advantages of Converting Flush Medians to Two-Way Left-Turn Lanes

Reduced travel time
Improved capacity
Reduced crash frequency
More flexibility
Public preference

Two-way left-turn lanes increase roadway access instead of controlling it. These are generally used on arterials to provide access for closely spaced, low-volume ramps. The optimum median width for two-way left-turn lanes ranges from *10 to 16 feet.*
Nontraversable medians (raised curbs, concrete median barriers) may be considered for locations where two-way left-turn lanes are unsuitable.

Median design may require tradeoffs by the engineer. For locations with restricted right-of-way, a wide median may not be possible if it requires reducing areas adjacent to the traveled way. A reasonable border width serves as a buffer between private development and the roadway, plus space may be needed for sidewalks, highway signs, utilities, parking, drainage channels/structures, slopes, clear zones, and native plants.

For median widths of **40 feet or wider**, drivers are separated from opposing traffic with greater ease of operation, less noise, and reduced headlight glare at night.

For widths of **60 feet or greater**, medians can be landscaped as long as it does not compromise the roadside recovery zone. This width may not be appropriate for urban or signalized intersections.

FRONTAGE ROADS

The function of any frontage road depends on the character of the section as well as the type of roadway (major route or local street) it serves. These functions may include:

- Controlling access to the arterial
- Serving as a street for adjoining properties
- Maintaining traffic on each side of the arterial

Frontage roads separate local traffic from high-speed through traffic, and intercept resident/business ramps – preserving highway through character.

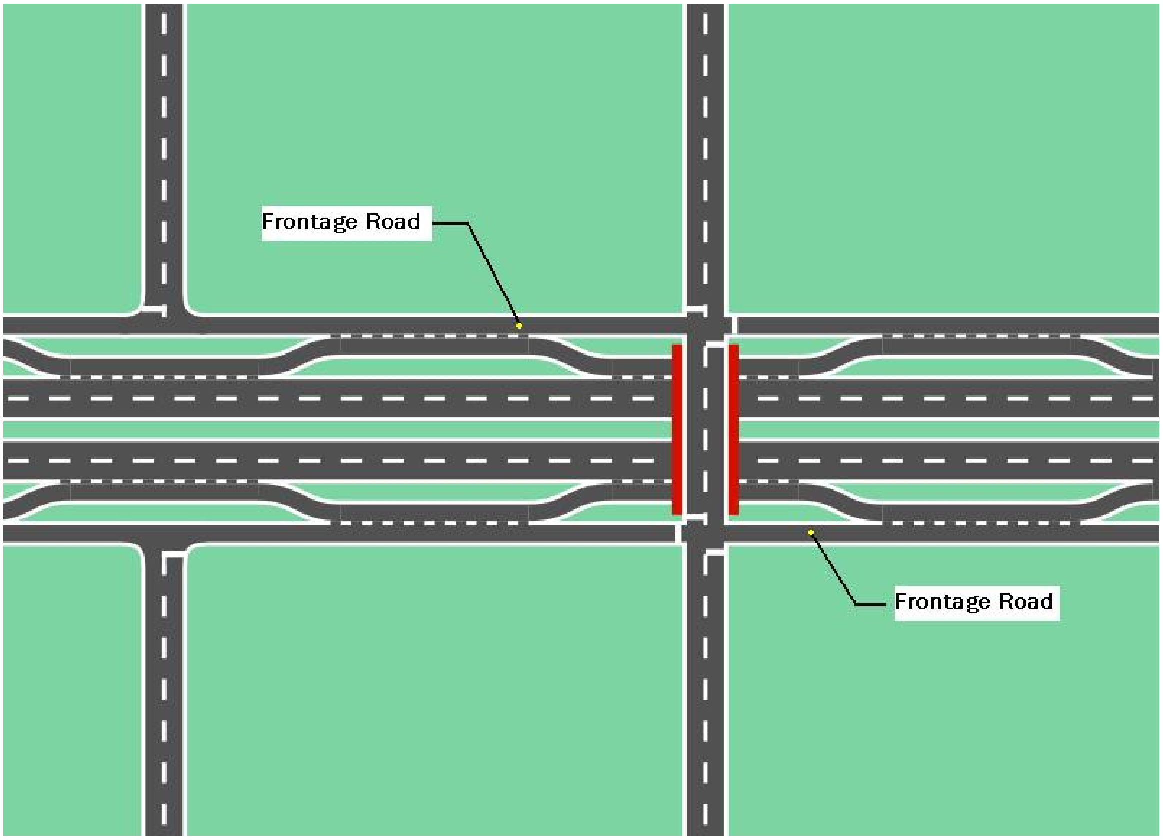
While frontage roads are used for all types of roadways – they are used most frequently on freeways to distribute and collect roadway traffic between local streets and freeway interchanges. Frontage roads help preserve roadway capacity and reduce crashes on the arterial streets.

Frontage roads are typically parallel to the main road, may be on one or both sides of the roadway, and may or may not be continuous. Using continuous frontage roads for high-speed arterials with intersections should not be used. Multiple through and turning movements at many closely spaced intersections can increase the potential for vehicle crashes. Frontage roads should be placed a considerable distance (150 ft minimum – urban) from the main line to improve traffic operations.

One-way frontage roadways are preferred due to their operational and safety advantages. This type of operation may be inconvenient for local traffic. However, the potential for pedestrian/vehicular conflicts is greatly reduced, as well as the needed width for both roadway and right-of-way. The roadway capacity is also maintained for freeways and frontage roads.

Two-way frontage roads are suitable for suburban/rural locations with irregular access points, or where one-way operation would create driver inconvenience. These may also be used where there are no parallel roads within a reasonable distance of the frontage roadway.

Connecting ramps are crucial to frontage road design. Simple openings or slip ramps are typically used for one-way frontage roads and slow-moving arterials. These should not be used for freeway - two-way frontage road connectors due to increased crash potential. For high-speed roadways (freeways, arterials), the connections need to be designed to allow for speed changes and vehicle storage.



Typical Frontage Road Example

OUTER SEPARATIONS

Outer separations are buffer areas between through-traffic roadways and local frontage road traffic. These separations also provide shoulder space and ramp connection area for the through roadways. *As the outer separation widths increase - the influence from local traffic on through traffic decreases.* Wide separations are suitable for landscape treatment and aesthetics. Suitable widths are also advantageous for intersections to minimize vehicular and pedestrian conflicts.

The cross-section of an outer separation depends on:

- **width**
- **type of arterial**
- **frontage road type**

The *AASHTO "Green Book"* provides a number of typical cross-sections for these types of outer separations.

NOISE CONTROL

Traffic noise is typically the resulting sound from vehicle engines, aerodynamics, exhaust, tire interaction with the roadway surface, etc. Designers should make every effort to minimize sound radiation along noise-sensitive areas. They should also review any noise ordinances or restrictions that could limit the types of equipment permitted or the hours of work. Coordination with local agencies is essential during the planning and design process for successful implementation. Location and design methods can be used to help reduce roadway traffic noise.

A standard method of sound measurement involves using the **A-scale** on a standard sound level meter to read effective decibels (dBA). Since these results are measured on a **logarithmic scale**, 10 dBA increases appear as half of the original noise level (i.e. 50 dBA noise level sounds half as loud as 60 dBA). Doubling the noise level results in only a 3 dBA increase (i.e. a single vehicle produces a noise level of 60 dBA, two vehicles at the same point produce 63 dBA, four vehicles 66dBA, etc.).

Sound decreases with distance at approximately *3 to 4.5 dBA* for each doubling of distance from the roadway.

Similar traffic noise produces different reactions depending on the environment. Area development typically affects the annoyance level – higher noise levels are tolerated in industrial areas versus residential ones.

Noise levels may also be an important consideration when choosing a roadway's design speed. Studies have shown that greatly reduced noise levels result in drivers underestimating their speeds and driving 4 to 6 mph faster. Drivers are likely to become desensitized to their own speeds due to reduced noise levels.

Design Procedures

In order to analyze the effects of roadway noise, the criteria for noise impacts must be established. Next, noise-sensitive areas (schools, churches, motels, parks, hospitals, residential areas, nursing homes, libraries, etc.) need to be identified. Existing noise levels can then be measured and roadway-generated noise levels predicted by current noise prediction methods. The prediction will typically produce the worst hourly traffic noise for the design year. Major factors include traffic characteristics, topography, and roadway characteristics.

Traffic Characteristics: *Speed* *Volume* *Composition*

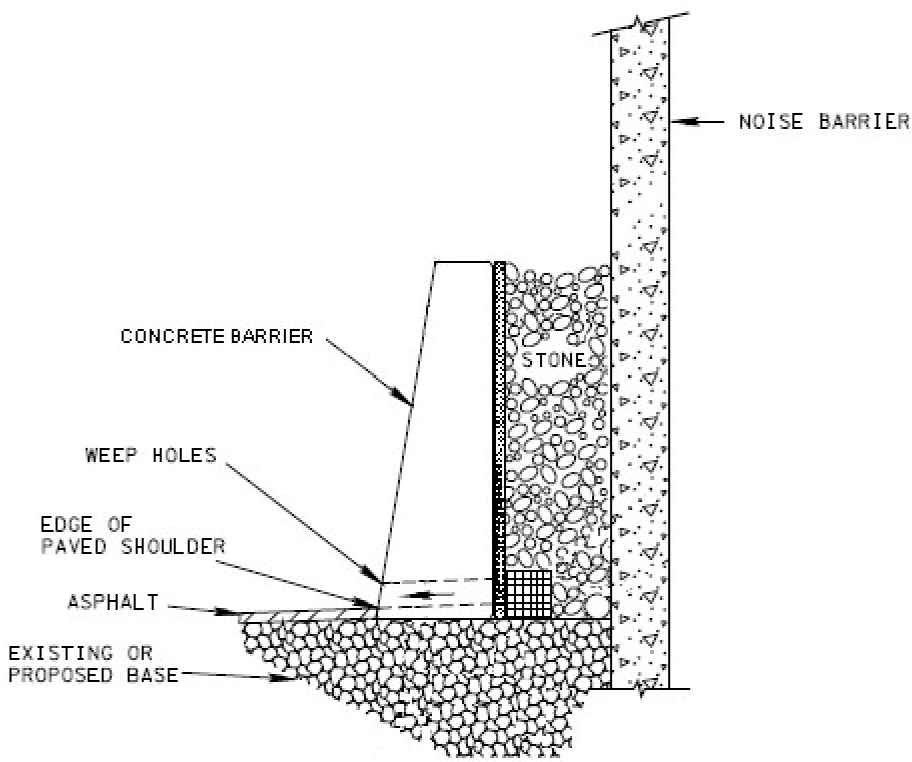
Topography: *Vegetation* *Distance* *Barriers*

Roadway Characteristics:
Configuration *Pavement type* *Grades* *Facility types*

The FHWA provides noise-abatement criteria and design noise levels according to land usage. AASHTO states that traffic noise impacts occur only for the following cases:

- Predicted noise levels approach or exceed noise-abatement criteria
- Predicted noise levels exceed predicted levels but are within noise-abatement criteria

Both of these specific situations should be analyzed to successfully assess the traffic noise impact for future projects.



Noise Barrier Example

Noise Reduction Design

Designers should ensure that the placement of any proposed noise barriers do not intensify the severity of any potential crashes. The barriers should allow for sign placement and lateral offsets to hazards outside the traveled way, where practical. Sufficient sight distance is also a crucial design factor for noise barriers. A barrier should be installed anywhere with stopping sight distances below minimum AASHTO values (i.e. inside curve locations).

For gore areas, noise barriers should begin or end a **minimum of 200 feet** from the theoretical noise.

Any potential noise attenuation should be built into the design process as early as possible. This will prevent costly revisions later in the project cycle. Typical traffic noise solutions involve using solid materials to block the line of sight between the source and its receptors. A popular method for noise reduction is to design a roadway that takes advantage of its terrain to form a natural sound barrier. Depressed roadway sections (below ground level) have the same effect as barriers. For elevated roadways, their embankments may block the line of sight to receptors and reduce potential noise.

Special sound barriers (concrete, wood, metal, masonry walls, etc.) may be needed for certain noise-sensitive areas. The use of earth berms has been shown to be aesthetically pleasing by blending in with the natural landscape. These berms may be used alone or in combination with walls or screens to meet their intended purpose.

Buffer plantings (trees, shrubs, or ground cover) provide significant aesthetic effects and some noise reduction but are inefficient sound shields due to air flow.

ROADSIDE CONTROL

The amount and character of roadside interference determines the performance of roadways without access control. Uncontrolled land development and access points typically produce lower roadway capacity, increased vehicle conflicts, and premature obsolescence. By regulating the location, design, and operation of ramps and roadside elements (mailboxes, signs, etc.), interference to through traffic can be minimized.

Driveways

Driveways are low-volume intersections whose operational effects are directly related to the functional classification of the road which they access. Although these ramps are important access points for residential and commercial use, their location or number can adversely impact traffic operations.

Driveways that may be used for either right or left turns increase through traffic interference and are unsuited for arterials. Eliminating left turns for drives on major streets can worsen traffic operations by forcing traffic to travel farther, etc. to reach their destination. Right turn only driveways are preferred for roadways with curbed medians, flush medians, or median barriers.

Driveway Design Objectives

Operation & efficiency of intersecting roadways
Reasonable property access
Sight distance for vehicles, pedestrians & sidewalk users
ADA requirements for pedestrians with disabilities
Bicycle lanes or paths
Public transportation locations

Several state and local governments have developed driveway regulations to maintain efficiency. These regulations may control location, design, right-of-way, signing, lighting, drainage, sight distance, curbs, and parking. Appropriate driveway designs should accommodate the anticipated types and volumes of vehicles.

Vertical profiles for driveways should allow efficient operations for entering or exiting vehicles. These alignments should minimize dragging, accommodate disabled pedestrians, supply adequate drainage structures, and prevent potential ponding.

For further information on driveway design, consult the *TRB Access Management Manual* and the *NCHRP Guide for Geometric Design of Driveways*.

Mailboxes

Mailboxes and newspaper tubes constitute a risk (either directly or indirectly) to motorists. They should be located to provide maximum convenience to the user while limiting any potential for crashes.

Mailbox & Newspaper Tube Risk Factors

Placement
Roadway cross-section
Sight distance
Traffic volume
Impact resistance

The crash potential involving carriers and motorists is impacted by carriers stopping and continuing travel on the roadway.

Mailboxes should be installed only on the right side of the roadway in the direction of travel – exception may be made for one-way streets where they can be used on the left side. Placement along high-speed, high-volume roads should not be used – if possible. Placement considerations should include minimum walking distance by the user, available stopping sight distance within the roadway, and corner sight distance.

Vehicles stopped at mailboxes should be clear of the traveled way and roadway traffic. Greater clearances for high traffic volumes. This may be remedied by placing mailboxes outside a wide usable shoulder or turnout.

Roadway Type	Shoulder/Turnout Width in Front of Mailbox
Rural Highway	8 feet
High-volume, high-speed	10 feet (12 feet for some conditions)

Shoulders or turnouts less than 8 feet may not be practical for low-volume, low-speed roads. It is recommended that the mailbox face be placed 8 to 12 inches outside the shoulder/turnout to provide space to open the mailbox door.

For additional guidance regarding mailboxes, please refer to the *AASHTO Roadside Design Guide.*

Fencing

Fencing is used by various highway agencies to delineate access control for roadways and reduce the potential of right-of-way encroachment. Fencing is usually installed along the right-of-way line.

Full access-controlled highways may be fenced in any area except:

- precipitous slopes
- natural barriers
- where not required for access control

Highway agencies typically have control of the type and location of access control fence. For areas where fence is not needed for access control, it will be the property of the landowner. The type of fence should be the most cost-effective that is best suited to the land usage.

TUNNELS

Roadway development may at times require tunnels to transport traffic either under/through natural obstacles or to minimize highway impacts on a community.

Tunnel Construction Warrants

Areas where land acquisition costs may exceed tunnel costs
Narrow right-of-way locations with minimal expansion areas
Long, narrow terrain ridges with environmental or economic concerns
Long or serial intersection areas with non-standard street patterns
Existing or proposed parks and natural reserves
Transportation facilities - railroads, airports, etc.

Major Categories of Tunnels

Mining Methods
- Hard rock
- Soft ground

Cut-and-Cover Methods
- Trench
- Cut-and-cover

Tunnel classifications are determined by their method of construction. Tunnels built by mining methods leave overlying rock and soil intact. This method is further divided into the types of proposed excavated material *(hard rock or soft ground).* Hard rock tunneling is typically the cheaper option due to structural demands and construction costs. Tunnels needing immediate and heavy support will usually require costly soft ground tactics *(shields, compressed air).*

Tunnels built by cut-and-cover methods are constructed from the surface. The trench type uses pre-fabricated sections that are sunk, joined, and backfilled at the site. For favorable environmental and construction conditions, the trench method may be the most economical method. Cut-and-cover tunnels are the most common type for urban shallow tunnels. For this method, an open cut is excavated, the tunnel is built, and then backfilled. For ideal conditions, cut-and-cover tunnels are the most inexpensive method for shallow depth tunnels – but any surface disruption or utility problems can make this very difficult and expensive.

Design Considerations

Tunnel lengths need to be as short as practical in order to keep down costs and to enhance user comfort. The horizontal alignment is a crucial design element. *Tangent designs help to minimize length, improve operating efficiency, and provide adequate sight distance.* Using curved tunnels may limit stopping sight distance. Therefore, it is important to thoroughly analyze sight distances for tunnel designs.

Vertical alignments are also important for tunnel design by addressing driver comfort. Many factors need to be considered in order to balance user needs (lights, ventilation, etc.) with roadway costs (construction, operation, maintenance and others).

Design criteria for tunnels is similar to those for grade separated facilities including:

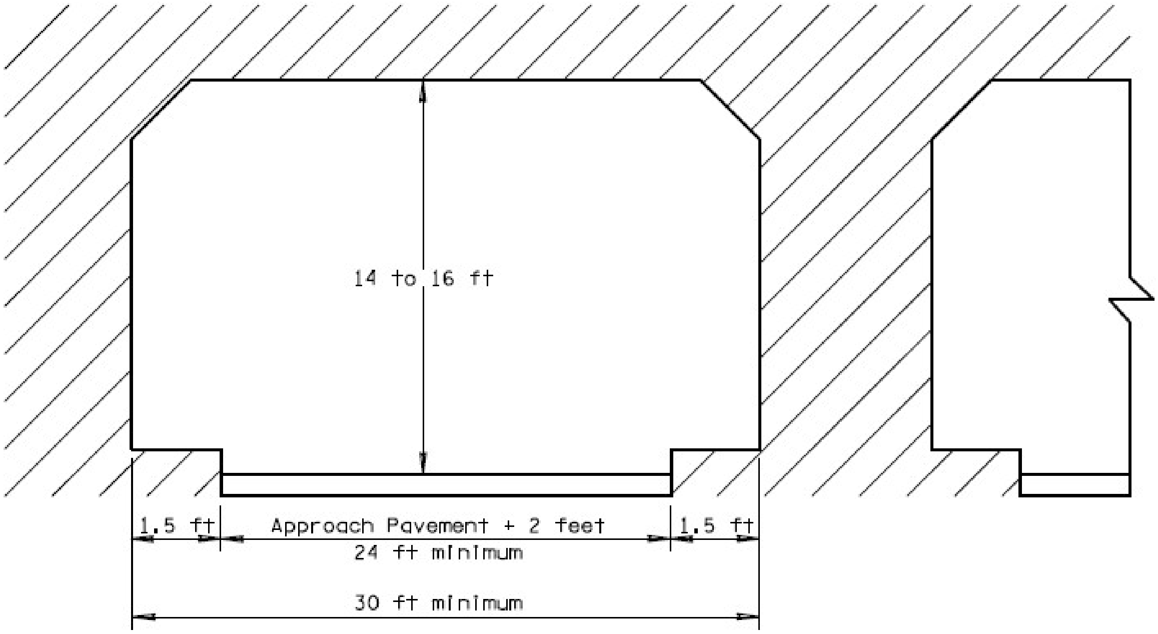
- Alignment
- Profile
- Clearances (vertical and horizontal)

The main difference is that minimum values are generally used for tunnels because of economic and right-of-way issues.

Additional lateral space (shoulders) is needed on tunnels to prevent major delays caused by stalled vehicles. Construction costs may prevent the use of shoulders in long tunnels. Determining shoulder widths within tunnels should be based on analysis of all factors pertaining to design. For tunnel locations without shoulders, arrangements should be made with emergency services to remove disabled vehicles.

<u>Two-Lane Tunnel Dimensions</u>

Minimum roadway width between curbs	approach pavement + 2 feet (24 ft min.)
Curb or sidewalk width	1.5 ft minimum
Total clearance width between walls	30 feet
Minimum vertical clearance	16 ft freeways (14 ft other highways)



The preferred two-lane tunnel cross-section contains two 12-ft lanes, 10-ft right shoulder, 5-ft left shoulder, and a 2.5-ft curb/sidewalk (on each side) with vertical clearances of 16 feet for freeways (14 feet for other roadways).

Although pedestrians are prohibited from freeway tunnels, raised sidewalks (2.5-ft wide) may be used beyond the shoulder space for emergency/maintenance walking access, or as a buffer between vehicles and tunnel walls/lighting fixtures.

PEDESTRIAN FACILITIES

Due to roadway interactions between pedestrians and motorized traffic, it is critical to integrate these during the project planning and design phases. The *Americans with Disabilities Act (ADA) of 1990* also requires that any new or reconstructed pedestrian facilities (sidewalks, shared-use paths, shared streets, or off-road paths) **must** be accessible to disabled individuals.

The typical range of values for walking speed varies from 2.5 to 6.0 ft/sec^2. The MUTCD recommends using a **4.0 ft/sec^2** as the walking speed value when calculating pedestrian clearance intervals for signalized intersections.

In order to accommodate pedestrians with visual, hearing, or cognitive impairments, various types of information (auditory, tactile, and kinesthetic) should be combined to render assistance. Different treatments may include: curb ramps; pedestrian islands; fixed lighting; pedestrian signals; audible signals; etc.

Sidewalks

Sidewalks are pedestrian paths that are located beside roadways and streets. Generally, anywhere roadside and land development impact pedestrian movement along a highway – a sidewalk should be provided. These are typically used in urban areas but rarely in rural areas. A border area is generally used in suburban and urban areas to separate roads from homes and businesses. Its primary function is to provide space for sidewalks. The minimum border width of **8 feet** is considered appropriate to provide space for sidewalks, lighting, fire hydrants, street hardware, vegetation, and buffer strips.

Sidewalk width (residential areas)	4 to 8 feet
Sidewalk width (adjacent to curb)	2 feet wider than minimum
Planted strip (between sidewalk and curb)	2 feet minimum
Sidewalk cross slopes	2 percent maximum

The additional sidewalk width (2 feet) for locations adjacent to the roadway curb provides sufficient space for roadside hardware, snow storage, open vehicle doors, bumper overhang, and moving traffic.

Pedestrian paths for bridges may differ from those of its roadway approaches due to costs and unique operational features. Flush shoulders should continue across bridge locations with low pedestrian traffic in order to provide sufficient escape area. These shoulders should not be interrupted by raised walkways, where possible.

Vertical curbs are typically adequate on low-speed streets to separate pedestrians from motorized traffic. A barrier-type rail may be used for high-speed roadways on structures with a pedestrian-type rail/screen on the walkways's outer edge. Approach walkways need to provide safe, direct access to the bridge walkway.

For sidewalk locations along high-speed roads, buffer areas may be utilized to distance the sidewalk from the traveled way.

Advantages of Buffer Areas

- Increased pedestrian distance from moving
- Aesthetics of the facility
- Reduced width of hard surface space
- Space for snow storage

A major disadvantage of buffers or plant strips is the possible need for additional right-of-way.

For more information regarding pedestrian facilities, refer to *Public Rights-of-Way Accessibility Guidelines*, and *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities.*

Grade-Separated Pedestrian Crossings

Grade-separated pedestrian crossings are generally used at locations where at-grade treatments are not feasible. These are used for separating pedestrians from vehicular traffic, enhancing pedestrian access, and improving the overall level of service. Grade-separations permit crossings at different levels (over or under the roadway) by pedestrians and vehicles. They also provide a pedestrian-safe refuge for crossing. The *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* provides more specific information for these structures.

Grade-Separated Pedestrian Crossing Factors

Pedestrian volume
Intersection capacity
Traffic volume
Conditions favoring usage

Heavy peak pedestrian movements (central business districts, factories, schools, athletic fields, etc.) may also need grade-separated pedestrian crossings. Governmental laws and codes should be consulted for pedestrian separation criteria and design guidelines.

Grade-separated crossings need to be located where pedestrians are naturally likely to cross the roadway. Pedestrians will typically use a crossing if it does not deviate significantly from a more direct route. They consider the safety of the grade separation versus the extra time and effort needed to cross the roadway. People are typically more resistant to use undercrossings versus overcrossings – mainly due to sight constraints. This may be minimized by providing continuous user vision, adding lighting, and installing ventilation systems.

Possible Grade-Separated Crossing Locations

Moderate to high pedestrian demand to cross roadway
Large numbers of children regularly crossing high-speed/high-volume roads
Unacceptable number of pedestrian conflicts with traffic
Documented collisions or close calls with pedestrians and vehicles

Pedestrian separation walkways should have a minimum width of **8 feet** – greater widths may be used for tunnels, high pedestrian traffic areas, and overpasses with a tunnel effect (from screens).

Presently, no universal treatment exists to prevent vandals from dropping objects from overpasses. There are no absolute warrants to address as to where and when barriers should be used to discourage the throwing of objects. The economy in design plus clear sight lines must be balanced against limiting potential pedestrian damage.

Possible Overpass Locations (with screens)

- Schools, playgrounds, etc. – where children may be unaccompanied
- Large urban pedestrian overpasses – not under police surveillance
- Where history indicates a need

Curb Ramps

Curb ramps provide access between the roadways and sidewalks for pedestrian crossings. These facilities are required by law to be accessible to and usable by disabled individuals (i.e. mobility, visual impairments, etc.).

Curb Ramp Design Factors

sidewalk width
sidewalk location
curb height & width
turning radius & curve length
street intersection angle
sign & signal locations
drainage inlets
utilities
sight obstructions
street width
border width

The *Public Rights-of-Way Accessibility Guidelines* provide the following guidance for curb ramps:

Minimum curb ramp width	4 feet
Maximum curb ramp grade	8.33%
Sidewalk cross slopes	2% maximum
Top level landing area	4 ft x 4 ft (no obstructions, 2% maximum cross slope)

Basic types of curb ramps have been established for use at intersections – depending on their geometric characteristics.

Perpendicular curb ramps contain the entire grade differential outside of the sidewalk. This design does not require any walking across the ramped area.

Parallel curb ramps are incorporated into the sidewalk. The designer should take measures to avoid any potential ponding or sediment accumulation.

Combination curb ramps merge aspects of both perpendicular and parallel ramps. A sloped section ascends to a lower landing (lower than full curb height) and then from the landing to the sidewalk. This design prevents water and debris accumulation.

Diagonal curb ramps are single perpendicular ramps at corner apexes that serve two crossing directions. This configuration is typically not suitable for moderate to high traffic areas due to possible user confusion – separate curb ramps for each crossing is the preferred treatment.

<u>Curb Ramp Guidelines</u>

Curb ramps should not project into the traveled way
Ramp area should be protected
Curb area should be used at sites with parking lanes
Locations should be coordinated with crosswalk lines

For additional guidance, please refer to the *MUTCD,* the *Public Rights-of-Way Accessibility Guidelines,* and *AASHTO's Guide for the Planning, Design, and Operation of Pedestrian Facilities.*

Curb Ramp Examples

BICYCLE FACILITIES

Bicycles continue to be a popular mode of transportation and their facilities should be a major consideration for any roadway design. The main factors to consider for accommodating bicycles include:

- Type of bicyclist being served by the route (experienced, novice, children)
- Type of roadway project (widening, new construction, resurfacing)
- Traffic operations & design characteristics (traffic volume, sight distance, development)

Existing roads and streets provide the majority of the required network for bicycle travel. Designated bikeways may be needed at certain locations to supplement the existing road system. Transportation planners and designers list the following factors as greatly impacting bicycle lanes: *traffic volume; average operating speed; traffic mix; on-street parking; sight distance; and number of intersections.*

Basic Types of Bicycle Facilities

Shared lane: typical travel lane shared by both bicycles & vehicles
Wide outside lane: outside travel lane (14 ft minimum) for both bicycles & vehicles
Bicycle lane: part of roadway exclusively designated (striping or signing) for bicycles, etc.
Shoulder: roadway paving to the right of traveled way for usage
Multiuse path: physically separated facility for bicycles, etc.

At locations without bicycle facilities, other steps need to be considered for enhancing bicycle travel on roads and streets. The following improvements (low to moderate cost) can help to reduce crash frequency and allow for bike traffic:

Paved roadway shoulders
Wider outside traffic lanes (14 ft min.) – if no shoulders
Bicycle-friendly drainage grates
Manhole covers at grade
Smooth, clean riding surface

AASHTO's *Guide for Development of Bicycle Facilities* provides specific guidance regarding bicycle dimensions, operation, and needs – which determine acceptable turning radii, grades, and sight distance.

The main differentiation between bikes and other vehicles is that the bicycle and rider are considered together as a system. Driver characteristics for motor vehicles are important but the driver-vehicle interface is rarely considered.

Typical bicyclist requirements: 3 feet lateral space
7.5 feet height

Required track width: 0.7 feet @ 7 mph or greater
2.5 feet @ 3 mph or greater

These track widths are not comfortable for riders – greater separation from traffic, and more maneuvering space is preferable.

BUS TURNOUTS

Bus turnouts are designed to separate buses from roadway traffic. Their intent is to provide safe access in the most efficient way possible.

Freeways

The purpose of bus turnouts is to provide adequate space (away from the traveled way) for bus deceleration, standing, and acceleration.

Bus Turnout Design Elements

Separation from traveled way
Passenger platforms
Ramps
Stairs
Railings
Signs
Markings

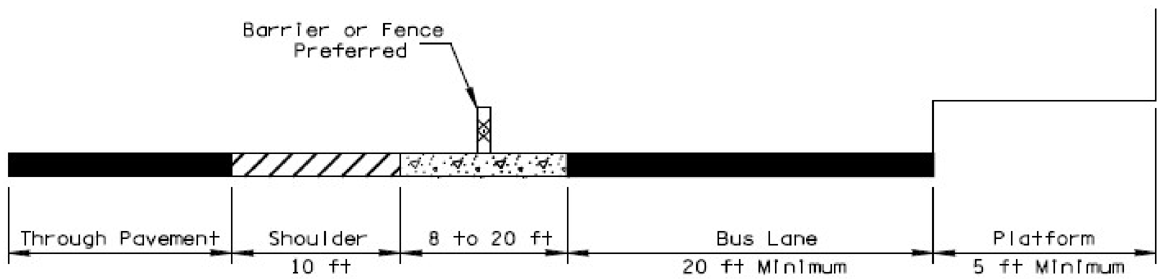
Speed-change lanes should have sufficient length for buses to enter or exit the roadway at average running speed without passenger discomfort. *Acceleration* lanes need to have above-minimum lengths to allow for lower accelerations of loaded buses. Different pavement colors and textures may be used to discourage through-traffic encroaching/entering the bus stop.

Freeway Bus Turnout Dimensions

Bus standing area/speed-change lanes width (including shoulders) *20 ft*

Dividing area between outer shoulder edge and edge of bus turnout lane *20 ft or more (4 ft minimum)*

Pedestrian loading platform width *5 ft minimum (6 – 10 ft preferred)*



Typical Bus Turnout

Arterials

Bus turnouts can substantially reduce the amount of interference between buses and other arterial traffic. In many cases, sufficient right-of-way may not be available to allow turnouts in the arterial border area. Turnouts should be provided whenever practical.

Effective Bus Turnout Characteristics

- Deceleration lane or taper for easy entrance to loading area
- Adequate standing space for maximum number of vehicles expected at one time
- Merging lane for easy reentry to roadway

A minimum deceleration lane taper of *approximately 5:1* (longitudinal to transverse) is intended to encourage buses to decelerate clear of roadway traffic before stopping. It is desirable to provide a length that permits deceleration from highway speeds.

Loading Area: 50 ft length per bus
10 ft wide (12 feet desirable)
3:1 maximum reentry taper

Two-Bus Loading Area: 180 ft minimum total length (midblock location)
150 ft near-side location
130 ft far-side location
10 ft loading area width

Turnout lengths should be increased by 13 to 16 feet for loading area widths of 12 feet.

For additional information on bus turnouts, please refer to *AASHTO Guide for Design of High-Occupancy Vehicle (HOV) Facilities* and *Guidelines for the Location and Design of Bus Stops.*

Park-and-Ride Facilities

Park-and-ride facilities are parking areas with connections to public transit that allow commuters to change mode of travel for continuing their journey. These facilities differ from typical parking lots by their various activities. Park-and-rides need to be close to residential areas to minimize single occupant travel but far enough from the city's center to prevent land costs from being prohibitive. Location factors can also include acquisition costs, terrain, connector road capacity, and surrounding land usage.

Location Considerations

Visible to attract commuters
Adjacent to streets and roadways
Prior to traffic bottlenecks
Close to residential areas

Parking lot size depends on existing parking lot characteristics, design volume, and available land. Each park-and-ride should contain a separate parking area with drop-off facilities near station entrances, and parking for passenger pickup. User conflicts may be minimized by considering bus loading/unloading, taxi service, bicycle parking, and parking for disabled individuals (see *ADA Accessibility Guidelines – ADAAG*).

Park-and-Ride Dimensions

Bus roadway width: 20 ft minimum (to allow passing)

Parking spaces: 9 ft x 20 ft (full-size cars)
8 ft x 15 ft (subcompact cars)

Sidewalks: 5 feet wide (minimum)

Loading areas: 12 feet wide

Parking area grades: 1% minimum
2% desirable
5% maximum

Entrances & exits: one for every 500 parking spaces

Curb return radii: 30 ft minimum

Access points should be located with minimal disruption to through traffic – a minimum of 300 feet from other intersections. These points need to have sufficient sight distance for entering and exiting vehicles (300 ft minimum corner sight distance). Access to lots should be avoided on crest vertical curves.

Shelters should be installed at main passenger loading areas to protect transit patrons. These need to be large enough for off-peak passenger volumes but may be larger where practical. It is not critical to accommodate the ultimate passenger demand at initial construction due to ease of future shelter expansion.

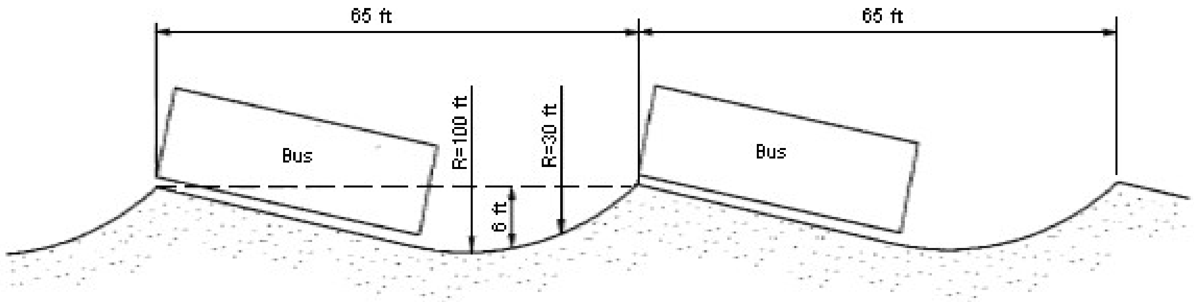
Shelter size = (Anticipated number of patrons) X (3 to 5 ft^2)

Bus-loading designs depend on the anticipated bus traffic. The two predominant bus-loading areas designs are:

Parallel

Sawtooth

Sawtooth arrangements (typically preferred) are easier for buses to bypass standing buses. Useful for sites where two buses are expected at the same time.



Typical Sawtooth Bus Loading Design

Parallel designs allow loading two buses (95 ft length) – 45 ft for each additional space. The loading area should have a minimum width of 24 feet for passing.

For additional guidance, please see *AASHTO Guide for Design of High-Occupancy Vehicle (HOV) Facilities*, *TCRP Report 19, Guidelines for the Location and Design of Bus Stops*, and *AASHTO Guide for the Design of Park-and-Ride Facilities*.

ON-STREET PARKING

On-street parking facilities for urban and rural arterials may be considered to accommodate existing and proposed land use. These facilities are typically the most common and convenient type of short-term parking. On-street parking is suitable for low-speed (less than 30 mph) and low-volume (less than 15,000 vehicles/day) roadways. Any urban space available for parking may be competing with bicycle lanes, pedestrian walkways, or roadway enhancements.

<u>Considerations For On-Street Parking</u>

- Specific function of street
- Traffic operations (existing and proposed)
- Roadway width
- Adjacent land use
- Traffic volume

Parallel parking spaces are used for the majority of on-street parking. Dimensions for these spaces depend on whether maneuvering space is included in the stall or separate. The *Manual on Uniform Traffic Control Devices (MUTCD)* contains further details regarding parallel parking dimensions.

Length of parking space (including maneuvering space) – 22 to 26 feet
(separate maneuvering space) – 20 feet

Minimum width of a parking lane – 8 feet

Desirable width – 10 to 12 feet (sufficient for commercial vehicles, buses and bikes

Space widths of 7 feet have been successfully used for roads with low-speeds (30 mph or less) and mainly passenger vehicle traffic.

Angle parking is another type of on-street parking. Extra care should be taken when using this design due to different vehicle lengths and sight distance problems associated with heavy vehicles (long vehicles can interfere with the traveled way).

Back-in/head-out diagonal parking is another viable parking option due to its improved visibility upon exiting. Vehicle maneuvering is typically easier and simpler with convenient placement for loading and unloading. Caution should be taken to prevent interference with utility poles, parking meters, etc. from vehicles with long overhangs.

Land access and mobility demands are equally important for urban collector streets.
A 36 ft roadway cross-section consisting of two 11 ft travel lanes and a single 7 ft parking lane on each side is frequently used for urban residential collectors with passenger vehicle traffic.

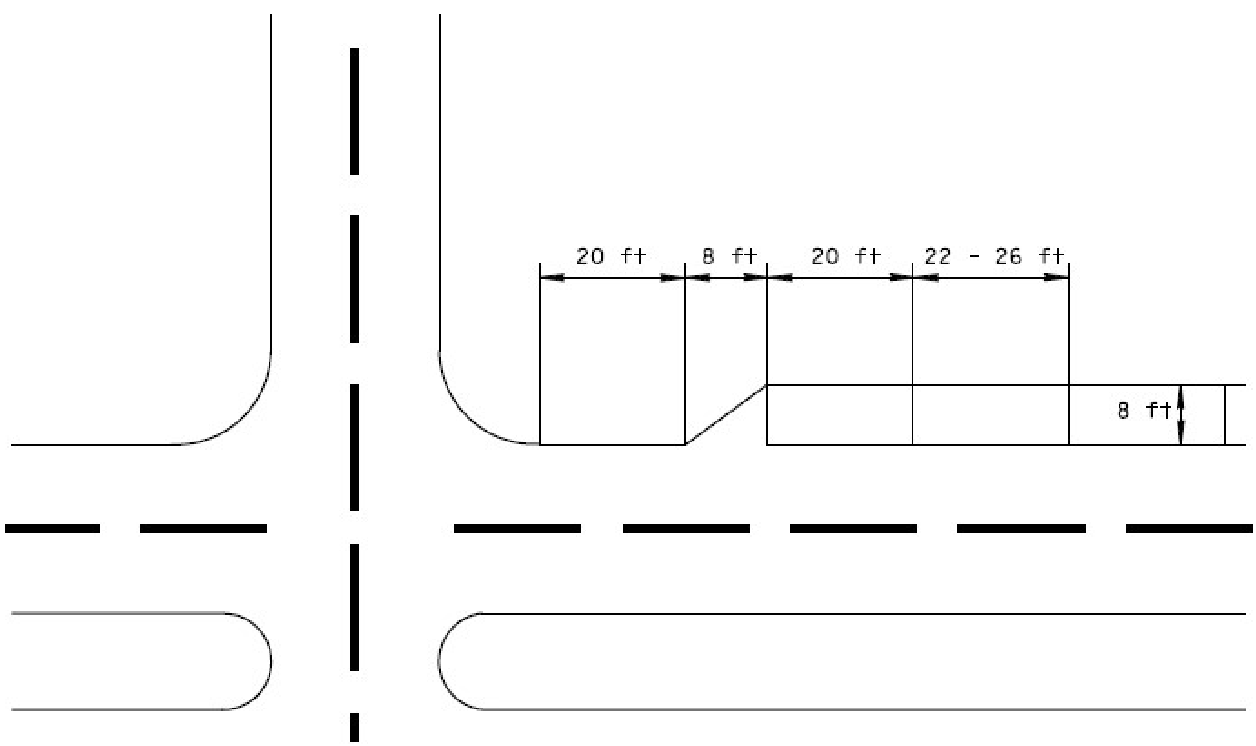
Local Streets

A 26 ft wide urban roadway with a single through lane and parking on both sides is typically used for residential streets. Adequate roadway width ensures that at least one travel lane is available in areas with heavy parking. Two-way movement can usually be accommodated in areas with intermittent parking on both sides of the roadway.

Traffic markings for parking spaces are highly recommended to identify the available areas, encourage orderly and efficient usage, and prevent encroachment on other designated areas (bus stops, loading zones, approaches, fire hydrants).

For areas with a significant number of pedestrian crossings, the relationship between parking lanes and intersections should be considered. At sites where parking lanes are carried to the intersection, vehicles may use the parking lane as a right-turn lane resulting in operational inefficiencies or crashes with roadside elements.
Two methods are commonly used to address this problem:

- End the parking lane a minimum of 20 feet prior to the intersection
- Prohibit parking a specified distance to create a short turn lane.



Parking Lane Transition at Intersection

<u>**Negative Aspects of On-Street Parking**</u>

Decreased through-traffic capacity
Disrupted traffic flow
Increased crash potential

SUMMARY

The AASHTO "Green Book" defines a **roadway cross-section** as *"a vertical section of the ground and roadway at right angles to the centerline of the roadway, including all elements of a highway or street from right-of-way line".* Along with the vertical alignment (grades and vertical curves) and horizontal alignment (tangents and curves), the roadway cross-section (lanes and shoulders, curbs, medians, roadside slopes and ditches, sidewalks) helps provide a three-dimensional roadway model. Its ultimate goal is to provide a safe, smooth-flowing facility that is crash-free.

This course focused on the geometric design of cross-sections for modern roads and highways. The participant should now be familiar with the general concepts for designing roadway cross-sections. The course objective was to provide an in-depth look at the principles to be considered when selecting and designing a roadway cross-sections.

Course topics covered include:

Medians
Frontage roads
Outer separations
Noise control
Roadside control
Tunnels
Pedestrian facilities
Bicycle facilities
Bus turnouts
On-street parking
Sideslopes

A Policy on Geometric Design of Highways and Streets (also known as the "Green Book") published by the American Association of State Highway and Transportation Officials (AASHTO) is considered to be the primary guidance for U.S. roadway design. For this course, **Chapter 4 - Cross-Section Elements (Sections 4.11 through 4.20)** was used exclusively for fundamental roadway geometric design principles.

The fundamental objective of good geometric design will remain as it has always been **– to produce a roadway that is safe, efficient, reasonably economic and sensitive to conflicting concerns.**

REFERENCES

A Policy on Geometric Design of Highways and Streets, 6th Edition.
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Note: All equations contained within this course are from this text unless noted otherwise.

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