Chapter Outline:

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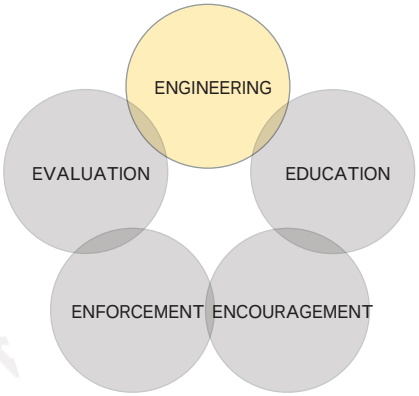
7.3 Linear Bicycle Facilities - Off Road
7.4 Bicycle Friendly Intersections & Traffic Calming
7.5 Bicycle Signage
7.6 Ancillary Features



CHAPTER 7: DESIGN GUIDELINES

7.0 Design Principles

These recommended guidelines have been tailored to meet the specific facility development needs of Carrboro's bicycle network. It is the intent of this plan to originate from and adhere to national design standards as defined by the American Association of State Highway Transportation Officials (AASHTO), the Americans with Disabilities Act (ADA), the Federal Highway Administration (FHWA), the Manual on Uniform Traffic Control Devices (MUTCD), and the NCDOT. Should the national standards be revised in the future and result in discrepancies with this chapter, the national standards should prevail for all design decisions. For example, the 2009 update to MUTCD provides new guidance. This chapter utilizes some of these 2009 updates, including the use of the sharrow facility. In order for Carrboro to move forward with the objective of achieving a higher Bicycle Friendly Community designation level, the design and implementation of high quality bicycle and greenway facilities is of utmost importance.

The sections in this chapter serve as an inventory of bicycle and trail design elements/treatments and provide guidelines for their development. These treatments and design guidelines are important because they represent minimum standards for creating a bicycle friendly, safe, and accessible community. The guidelines are not, however, a substitute for a more thorough evaluation by a landscape architect or engineer upon implementation of facility improvements. Some improvements may also require cooperation with the NCDOT for specific design solutions.

The following are key principles for these design guidelines:

1. Carrboro will have both a thorough network of off-road trails and a complete network of on-street bicycling facilities. These two systems will be interconnected to make it possible for all destinations in Carrboro to be accessible by bicycle.

2. All roads in Carrboro are legal for the use of bicyclists (except those roads designated as limited access facilities which prohibit bicyclists). This means that most streets have bicycle facilities, and will be designed and maintained accordingly.

3. Bicyclists have a range of skill levels, from Type "B"/"C" inexperienced/ recreational bicyclists (especially children and seniors) to Type "A" experienced cyclists (adults who are capable of sharing the road with motor vehicles). These groups are not always exclusive – some elite-level athletes still like to ride on shared-use paths with their families, and recreational bicyclists will sometimes use their bicycles for utilitarian travel.

4. At a minimum, facilities will be designed for the use of Type "B" cyclists, with a goal of providing for Type "C" cyclists to the greatest extent possible. In areas where specific needs have been identified (for example, near schools) the needs of appropriate types of bicyclists will be accommodated.

5. Design guidelines are intended to be flexible and can be applied with professional judgment by designers. Specific national and state guidelines are identified in this document, as well as design treatments that may exceed these guidelines.

Fig. 7-1. A bicyclist utilizing Jones Ferry Rd. facilities.

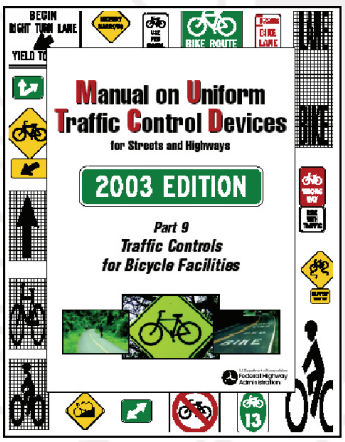


Fig. 7-2. Manual on Uniform Traffic Control Devices (MUTCD)

7.1 National and State Guidelines

The following is a list of references and sources utilized to develop design guidelines for Carrboro's Comprehensive Bicycle Transportation Plan. Many of these documents are available online and are a wealth of information and resources available to the public.

Federal Guidelines:

AASHTO Guide
Guide for the Development of Bicycle Facilities, 1999.
American Association of State Highway and Transportation Officials, Washington, DC.
www.transportation.org

AASHTO Green Book
Policy on Geometric Design of Streets and Highways, 2001.
American Association of State Highway and Transportation Officials, Washington, DC.
www.transportation.org

NCDOT
The North Carolina Bicycle Facilities Planning and Design Guidelines, 1994
NCDOT Division of Bicycle and Pedestrian Transportation
http://www.ncdot.org/transit/bicycle/projects/resources/projects_facilitydesign.html

MUTCD
Manual on Uniform Traffic Control Devices, 2003. Federal Highway Administration, Washington, DC.
http://mutcd.fhwa.dot.gov

State Guidelines:

PBIC / APBP
Bicycle Facility Selection: A Comparison of Approaches
Michael King, for the Pedestrian and Bicycle Information Center
Highway Safety Research Center, University of North Carolina – Chapel Hill, August 2002
http://www.bicyclinginfo.org/pdf/bikeguide.pdf

Bike Lane Design Guide (City of Chicago)
http://www.bicyclinginfo.org/pdf/bike_lane.pdf

Bicycle Parking Design Guidelines
http://www.bicyclinginfo.org/pdf/bikepark.pdf

San Francisco's Shared Lane Pavement Markings: Improving Bicycle Safety:
http://www.bicycle.sfgov.org

Local Guidelines:

Downtown Carrboro: New Vision (Downtown Visioning Charrette Report (2001)
http://www.ci.carrboro.nc.us/pzi/PDFs/ToCFinalVision.pdf

Carrboro Vision 2020 (2000)
http://www.ci.carrboro.nc.us/PZI/PDFs/Vision2020.pdf

Fig. 7-3. Examples of a paved shoulder facility.

7.2 Linear Bicycle Facilities - On Road

Paved Shoulder

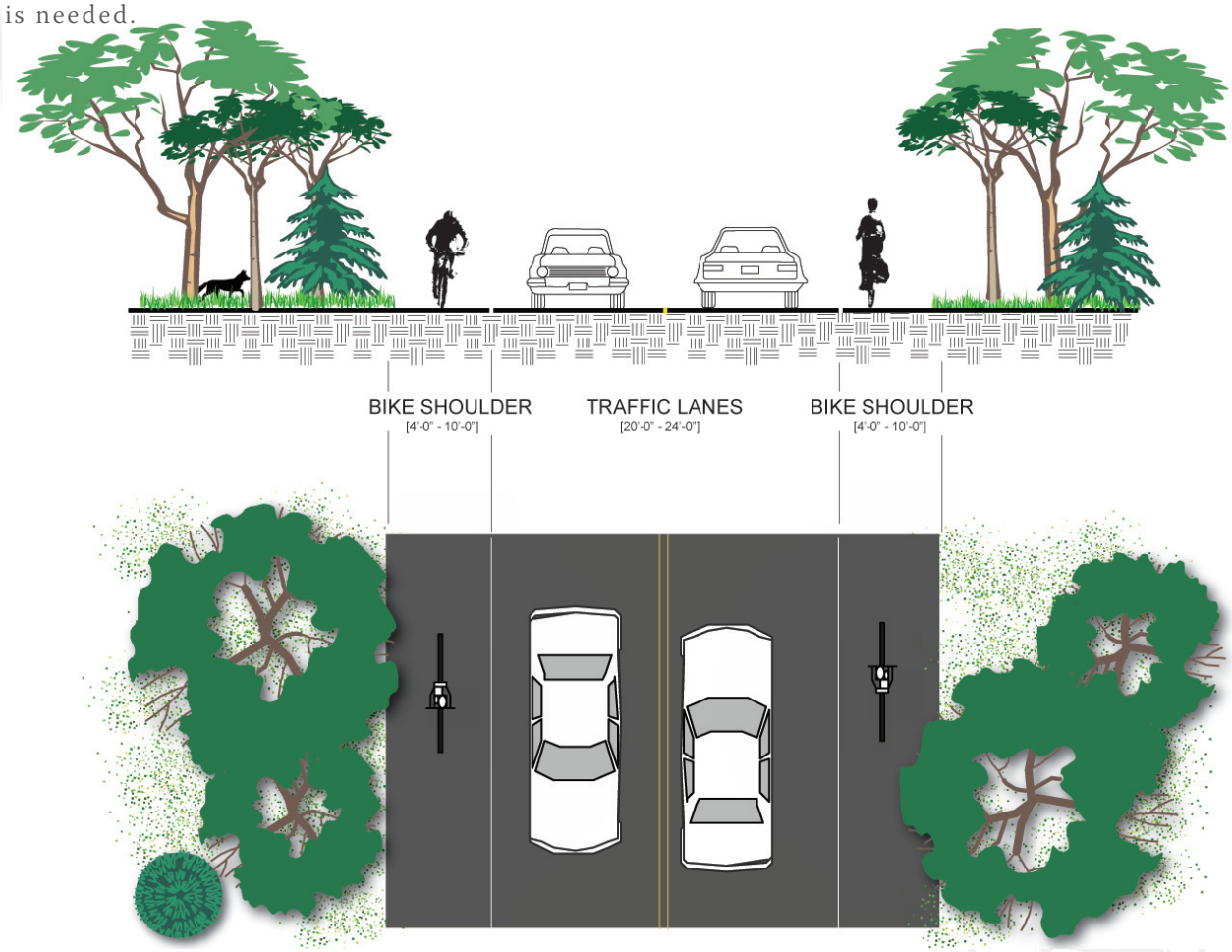
- For skilled bicyclists (Type "A" cyclists) who are capable of sharing the road with motor vehicles.
- Commonly located in more rural areas without curb and gutter
- Provide smooth pavement, free of debris.
- Provide shared road signage.
- Rumble strips hould be avoided, but if used, then a paved shoulder of wider width is needed.
- 4-foot width is recommended, but for speeds higher than 40 MPH and high ADT, a shoulder width of more than 4-feet is recommended.

Several roadways in Carrboro with **existing** paved shoulder facilities:

- NC 54
- Estes Dr.

Several roadways in Carrboro with **proposed** paved shoulders:

- Jones Ferry Rd.
- Old Greensboro Rd.
- Smith Level Rd.



Figs. 7-4 — 7-5. Two examples of existing bicycle lanes in Carrboro.

Bicycle Lane

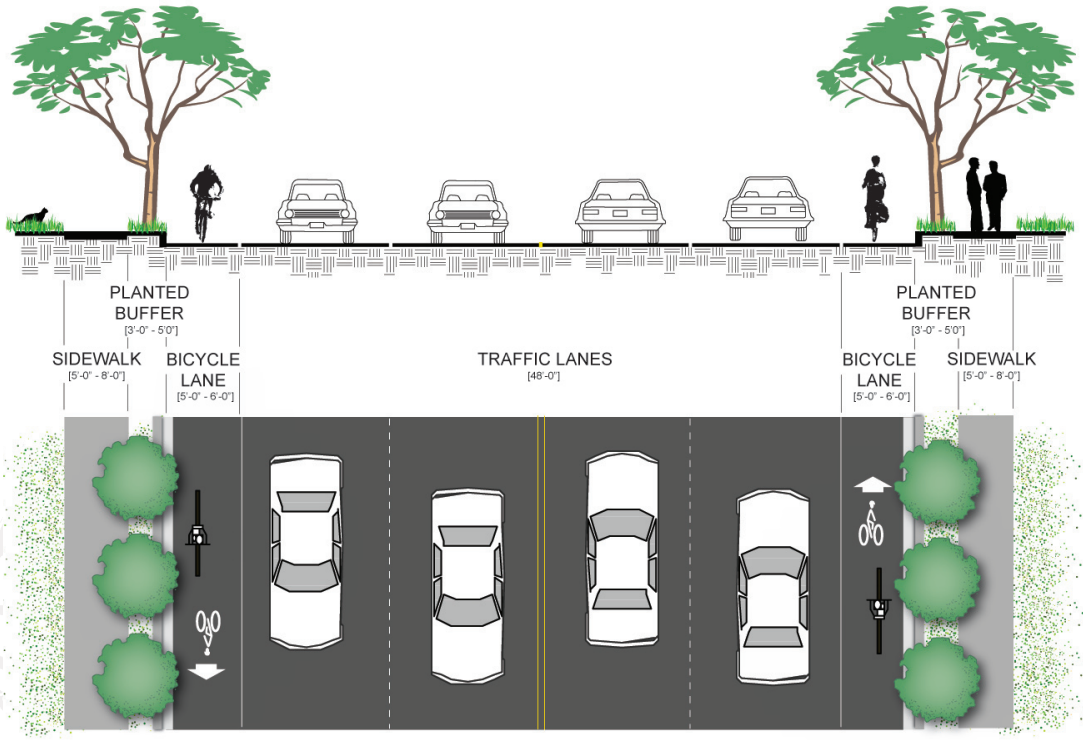
- Should be used on roadways with 3,000 or more ADT.
- For Type "A", "B" cyclists who are capable of sharing the road with motorists
- Recommended width of 6-feet. NCDOT recommends 4-feet from edge of curb (when no gutter pan is present); and 6-feet from edge of curb when gutter pan is present.
- Roadway paving should be at same grade as gutter pan. Ensure that there is no lip between bicycle lane paving and gutter pan paving.
- Not suitable where there are a high number of commercial driveways
- Suitable for 2-lane facilities and 4-lane divided facilities
- Roadway paving should be at same grade as gutter pan. Ensure that there is no lip between bicycle lane paving and gutter pan paving.

Several roadways in Carrboro with **existing** bicycle lanes:

- Hillsborough St.
- N. Greensboro St.
- Main St.
- Jones Ferry Rd.

Several roadways in Carrboro with **proposed** bicycle lanes:

- Davie St.
- Old Fayetteville Rd.
- Seawell School Rd.
- Weaver St.



Typical Pavement Markings for Bicycle Lanes

The Manual on Uniform Traffic Control Devices (MUTCD) provides guidance for lane delineation, intersection treatments, and general application of pavement wording and symbols for on-road bicycle facilities and off-road bike paths (http://mutcd.fhwa.dot.gov/pdfs/millennium/12.18.00/9.pdf). In addition to those presented in the MUTCD, the experimental pavement markings shown below may be considered.

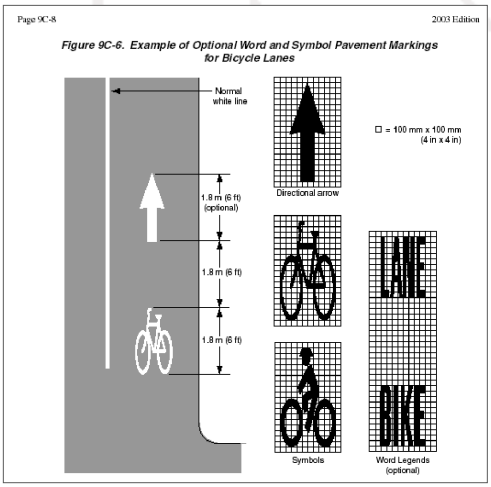


Fig. 7-6. Typical pavement markings for bicycle lanes from the MUTCD.

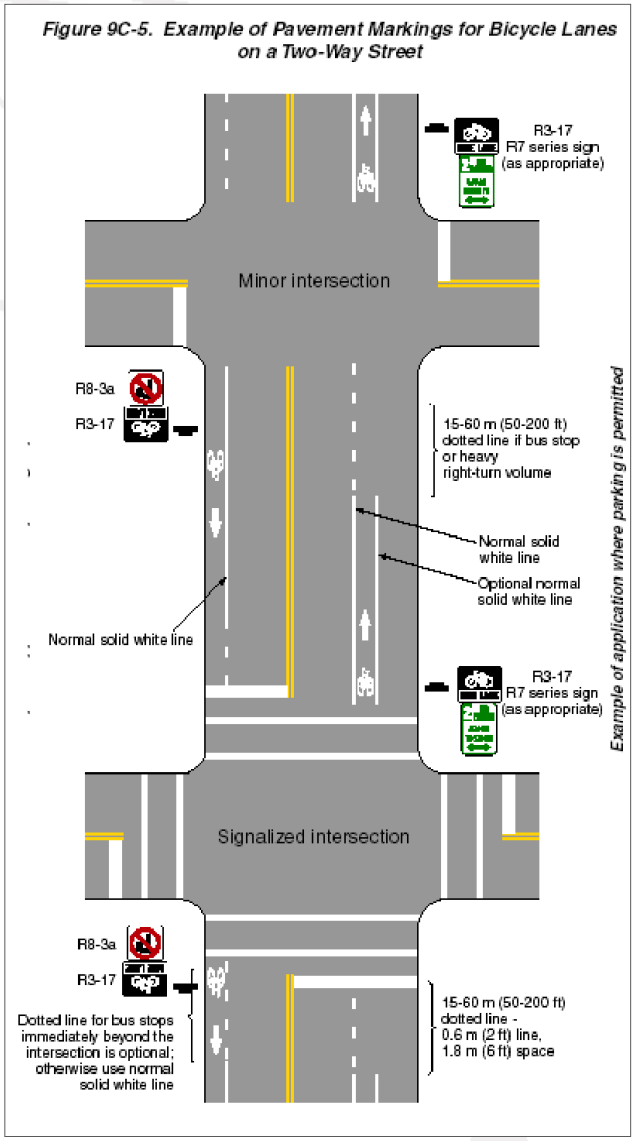


Fig. 7-7. MUTCD examples of optional word and markings within bicycle lanes.

Figs. 7-8. Two examples of sharrow marking.

Fig. 7-9. The city of San Francisco has developed these educational flyers for their installed sharrow markings.

Sharrow Marking

Some U.S. cities have created a bicycle shared lane arrow (or "sharrow" stencil) for use on designated on-road bicycle facilities where lanes are too narrow for striping designated bike lanes. Sharrow markings are recommended for Type "A" and "B" bicyclists who are comfortable sharing the road with motorists. The stencil can serve a number of purposes, such as making motorists aware of bicycles potentially traveling in their lane, showing bicyclists the appropriate direction of travel, and, with proper placement, reminding bicyclists to bike further from parked cars to prevent "dooring" collisions.

Denver, CO, and San Francisco, CA, have effectively used this treatment for several years. Other cities, such as Portland, OR; Los Angeles, CA; Gainesville, GA; Cambridge, MA; Oakland, CA; and foreign cities such as Paris, Brisbane, Zurich, and Buenos Aires have begun to utilize this new treatment as well.

The "sharrow" treatment was recently included in the future 2009 update of the MUTCD. This update has yet to be finalized, and according to the MUTCD website, the final version is anticipated during 2009.

- Sharrow marking is appropriate where speed limit does not exceed 35 MPH.
- Sharrow marking should be placed immediately after an intersection and at intervals not greater than 250 feet thereafter.
- Sharrow marking can be used with-or without on-street parking.

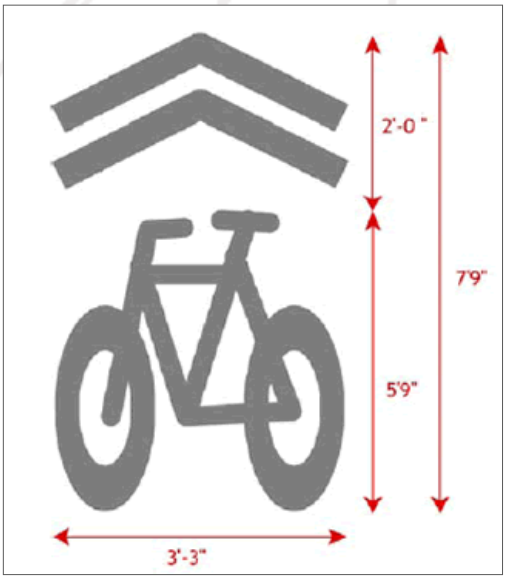


Fig. 7-10. Sharrow Stencil Dimensions

Roadways in/near Carrboro with **existing** sharrows:

- MLK Blvd. between Estes Dr. and Rosemary St.

Several roadways in Carrboro for **proposed** sharrows:

- Old Pittsboro Rd.
- Shelton St.
- Main St.
- Merritt Mill Rd.
- Colfax Rd.
- Roberson St.

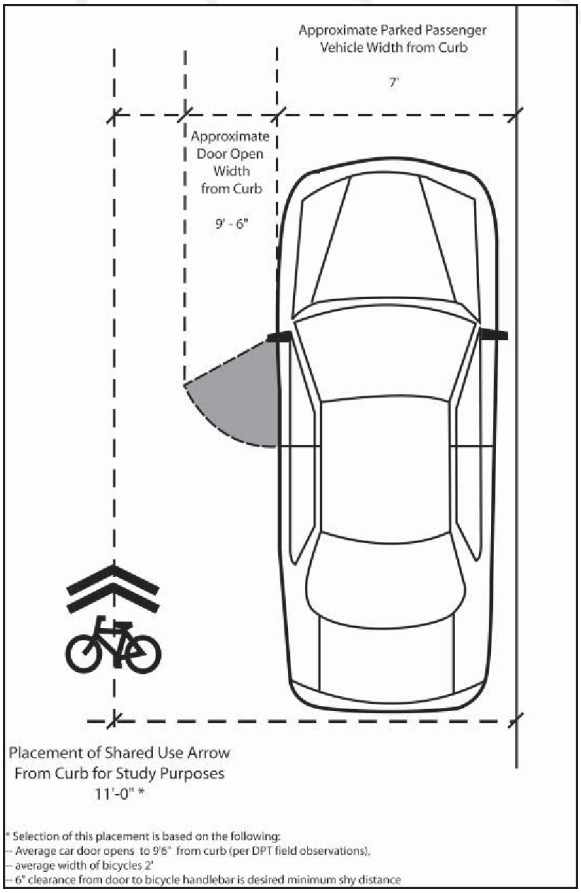


Fig. 7-11. Sharrow Placement Dimensions

Fig. 7-12 — 7-13. Examples of a sidepath in Durham, NC (left); and Sand City, CA (right).

7.3 Linear Bicycle Facilities - Off Road

Sidepath

- Accomodates all types of bicyclists
- This type of trail works best in corridors where there are limited driveway/ intersection crossings and more desirable destinations along one side of the roadway, or where no roadway space is available to provide bike lanes.
- The trail should be at least 10 feet wide (preferably 12 feet) with a 3-5-foot (preferably 6-foot) vegetated buffer where possible.
- A well-designed transition (at-grade crossing or appropriate signage) where the sidepath ends at the roadway or intersection is recommended so that the bicyclist can be safely directed into the correct flow of traffic.

Several roadways in Carrboro with **proposed** sidepaths:

- Old NC 86
- Dairyland Rd. (at end of Homestead Rd.)
- NC 54 from James St. to Anderson Park along Eubanks Rd.

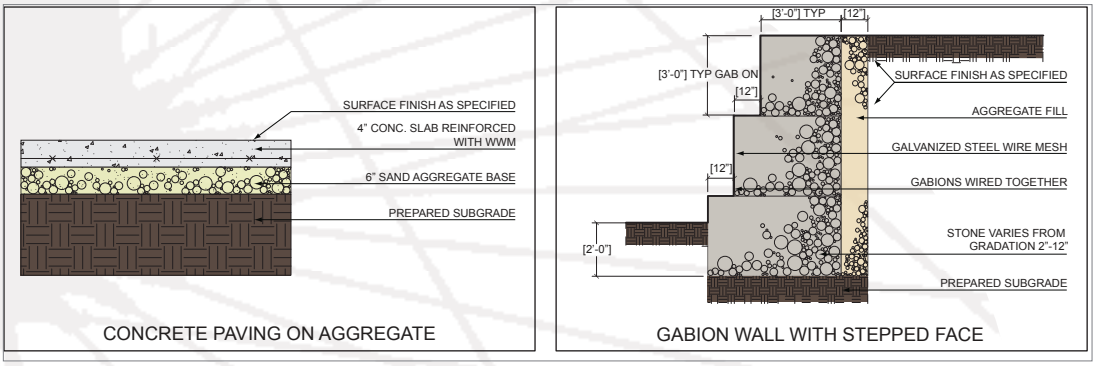


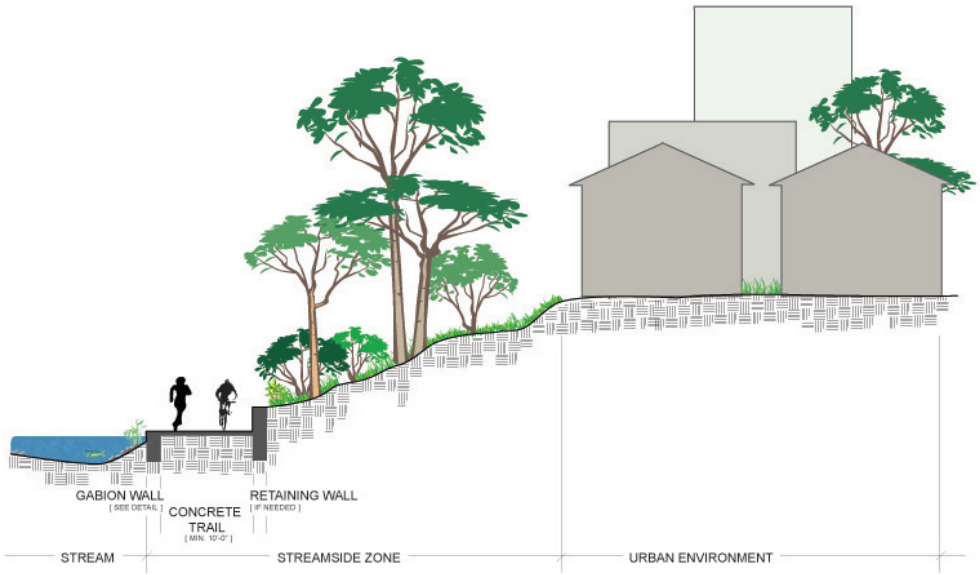
Fig. 7-14. Examples of stable construction elements.

Greenway Trails

The following pages focus on design guidelines for greenways. Greenways accomodate all levels of bicyclists but are the most comfortable for Type "C" cyclists, namely children.

Creekside Trail (Urban Areas Only)

- Located only in urban areas, where right-of-way constraints and channelized streams restrict trail development to the floodway.
- Typically positioned directly adjacent to the stream channel and are therefore subject to frequent flooding.
- Parking areas near urban creeks can also be retrofitted to accommodate this type of trail.
- When box culverts are built along creeks on planned trail routes, they should be designed to meet with this trail type, and should have sufficient space for trail users.
- Require hard paved surfaces of concrete to withstand high-velocity stream flows. May consider permeable paving treatments in more environmentally-sensitive areas.
- Retaining walls or other structural elements may also be required for stable construction and to protect the trail from erosion and flood damage.
- The installation of railings, benches, signage, and trash receptacles, that could obstruct flow during storm events, should be carefully considered.
- The use of retaining walls and seat walls is one way in which non-obtrusive amenities can be included.
- Special consideration should be given to the mitigation of impacts from trail construction on the natural environment.
- Minimum 10-foot width for multi-use trails.



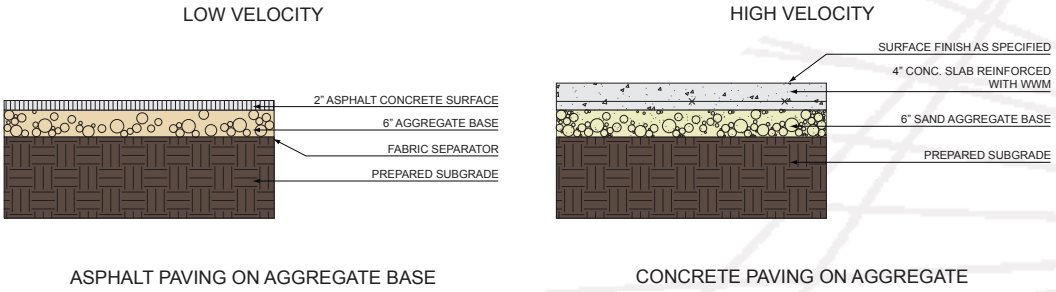


Fig. 7-15. Typical trail foundation details.

Floodway Trail (Limited Areas)

- Typically positioned within the floodway, but not directly adjacent to streams; some vegetative buffer between the stream and trail should be left intact.
- Subject to infrequent, periodic flooding.
- Require paved surfaces of either asphalt or concrete depending on frequency of flooding and expected velocity of flow. May consider permeable paving treatments in more environmentally-sensitive areas.
- Proper trail foundation (see Figure 7-15) will increase the longevity of the trail.
- No soft shoulder should be constructed due to flood considerations.
- All elements of the trail, including the trail tread, railings, benches, and trash receptacles, will be periodically flooded; design and materials should be carefully selected and sited accordingly.
- Special consideration should be given to the mitigation of impacts from trail construction on the natural environment.
- Minimum 10-foot width for multi-use trails.

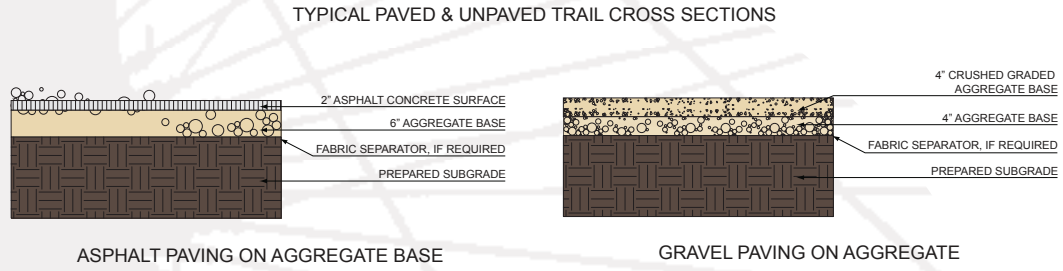


Fig. 7-16. Typical trail cross sections

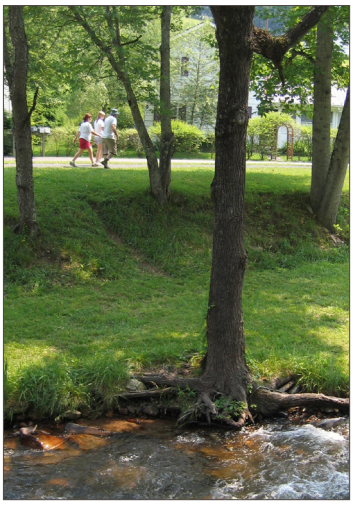


Fig. 7-17 — 7-18. A floodplain trail along a creek provides recreational opportunities.

Floodplain Trail

- Typically positioned outside the floodway, within the floodplain; significant vegetative buffer between the stream and trail should be left intact.
- Subject to occasional flooding, during large storm events.
- Paved asphalt recommended, though an aggregate stone surface may be adequate in some locations. May consider permeable paving treatments in more environmentally sensitive areas.
- Proper trail foundation (see Figure 7-16) will increase the longevity of the trail.
- Minimum 2-foot graded shoulder recommended.
- Minimum 10-foot width for multi-use trails.

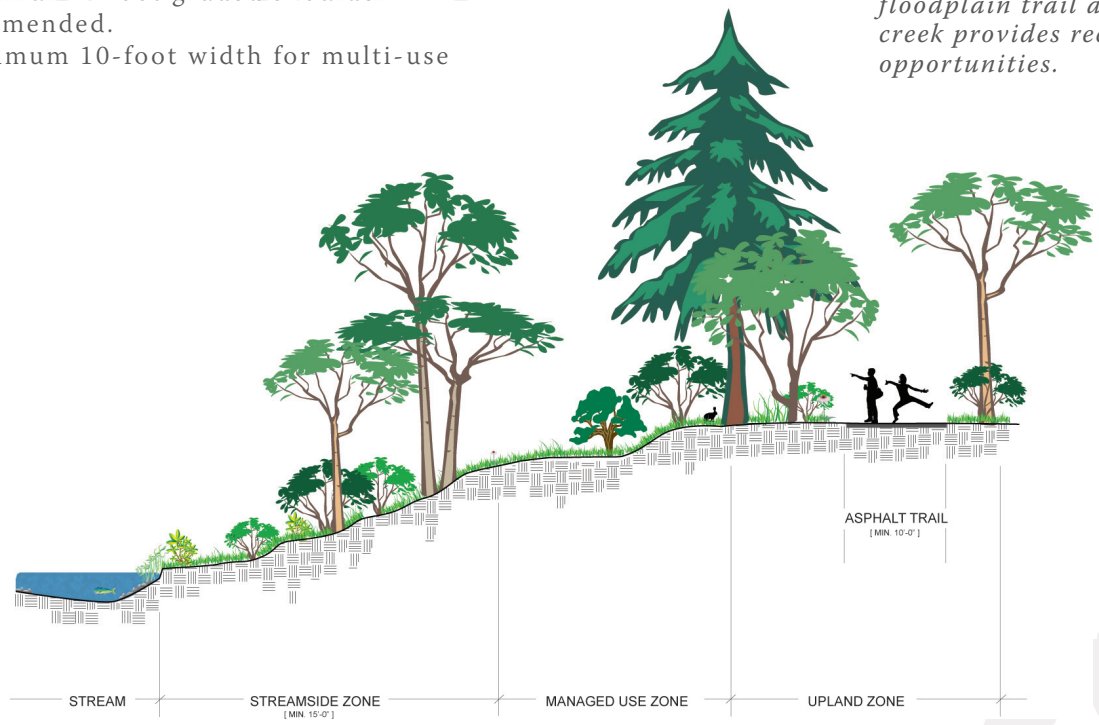
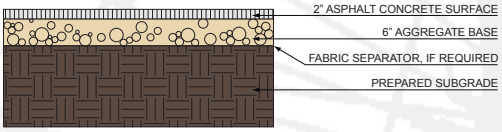


Fig. 7-19 — 7-20. Multi-use trails support all types of cyclists. Trails shown above are in Durham, NC.

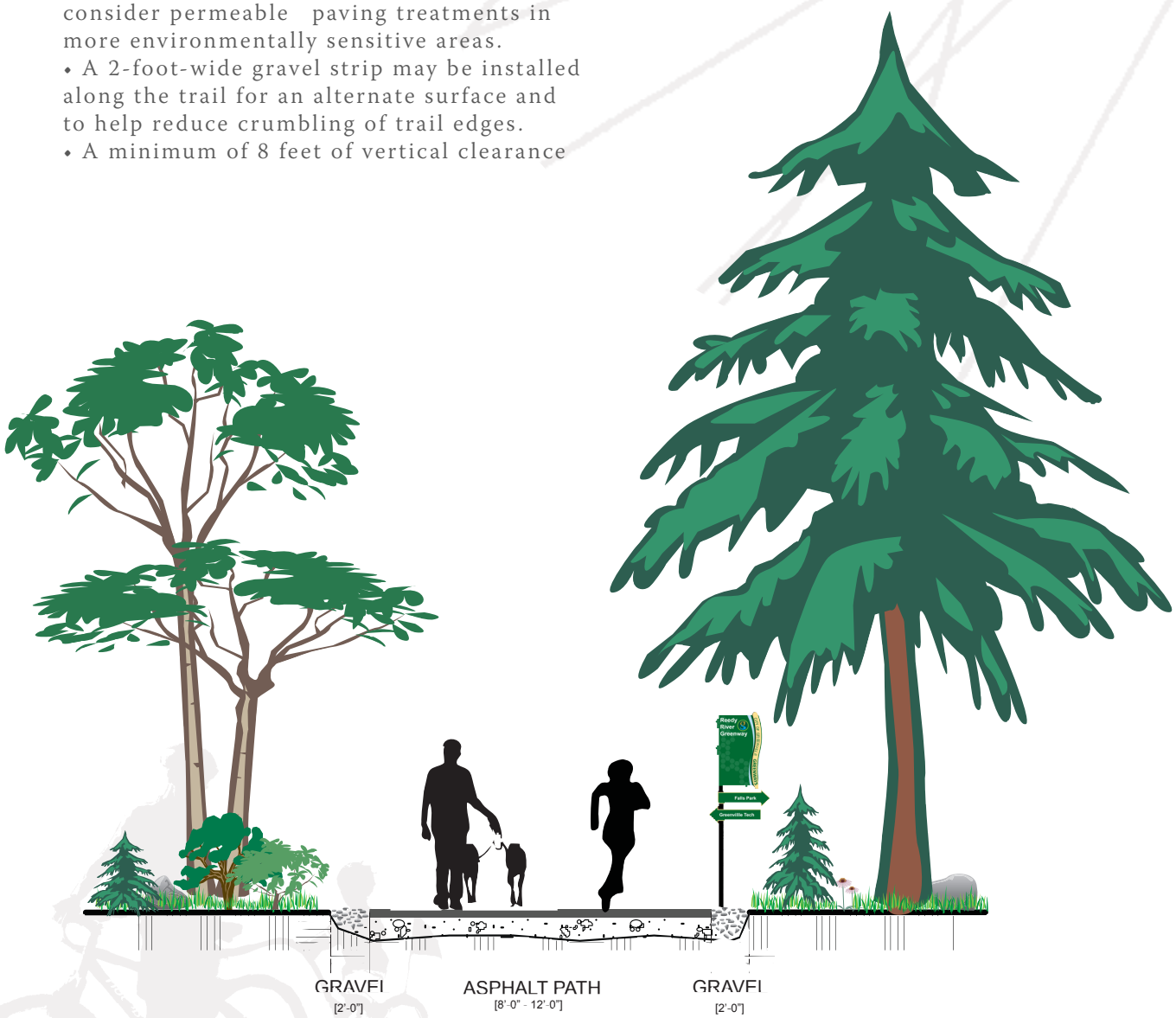


ASPHALT PAVING ON AGGREGATE BASE

Fig. 7-21. Typical paved trail cross section.

Multi-use Trail

- Minimum 10-foot width
- Proper trail foundation (see Figure 7-21) will increase the longevity of the trail.
- Paved asphalt recommended, May consider permeable paving treatments in more environmentally sensitive areas.
- A 2-foot-wide gravel strip may be installed along the trail for an alternate surface and to help reduce crumbling of trail edges.
- A minimum of 8 feet of vertical clearance



Trail Underpass
Trail underpasses typically utilize existing overhead roadway bridges adjacent to steams or culverts under the roadway that are large enough to accommodate trail users.

- Vertical clearance of the underpass should be at least 10-feet.
- Width of the underpass must be at least 12-feet
- Proper drainage must be established to avoid pooling of stormwater.
- Lighting is recommended for safety

Trail Overpass

Bridges are used for above-grade crossings and should be designed with specific structural engineering and safety considerations. If crossing an interstate highway, specific and stringent standards will apply.

- Safety should be the primary consideration in bridge/overpass design.
- Specific design and construction specifications will vary for each bridge and can be determined only after all site-specific criteria are known.
- Always consult a structural engineer before completing bridge design plans, before making alterations or additions to an existing bridge, and prior to installing a new bridge.
- A 'signature' bridge should be considered in areas of high visibility, such as over major roadways. While often more expensive, a more artistic overpass will draw more attention to the trail system in general, and could serve as a regional landmark.
- For shared-use facilities, a minimum width of 14-feet is recommended.
- Trail overpasses are prohibitively expensive and should only be placed in areas of substantial need.

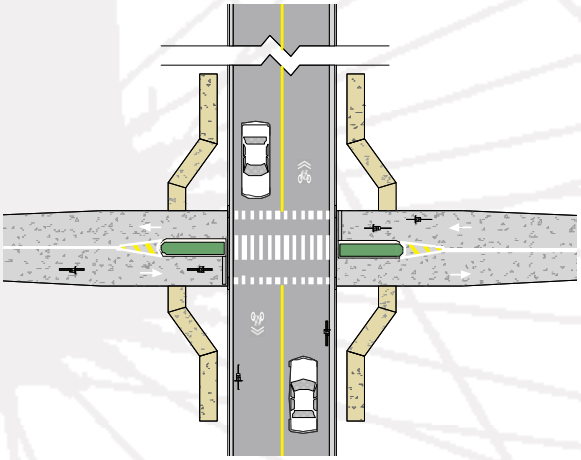


Fig. 7-22. Detail (left) and photo (above) showing Midblock Crossing with Shared Use Path.

7.4 Bicycle Friendly Intersections & Traffic Calming

Intersections represent one of the primary collision points for bicyclists. Generally, the larger the intersection, the more difficult it is for bicyclists to cross. On-coming vehicles from multiple directions and increased turning movements sometimes may make it difficult for motorists to see non-motorized travelers.

Most intersections in Carrboro do not provide a designated place for bicyclists. Bike lanes and pavement markings often end before intersections, causing confusion for bicyclists. Loop and other traffic signal detectors, such as video, often do not detect bicycles. Bicyclists wanting to make a left turn can face quite a challenge. Bicyclists must either choose to behave like motorists by crossing travel lanes and seeking refuge in a left-turn lane, or they may act as pedestrians and dismount their bikes, push the pedestrian walk button located on the sidewalk, and then cross the street in the crosswalk. In some situations bicyclists traveling straight may have difficulty maneuvering from the far right lane, across a right turn lane, to a through lane of travel. Furthermore, motorists often do not know which bicyclist movement to expect. The following pages provide treatments for these conditions.

Bike Trail & Roadway Intersections

- Include appropriate signage warning trail user of upcoming conditions.
- Either a median refuge island or crosswalk should connect the trail entrance to the roadway.
- Typically bollards may be used at the entrance of trails where passage of motor vehicles is prohibited and bicycles is permitted.
- The crossing should be a safe enough distance from neighboring intersections to not interefere with traffic flow.
- A roadway with flat topography is desirable to increase motorist visibility of the path crossing.
- In addition to signage, motorists and trail users can also be warned of the trail crossing with changes in pavement texture, flashing beacons, raised crossings, and striping.
- A refuge is most particularly needed in conditions exhibiting high volumes/speeds, where trail usage is significant, and/or where the primary user group crossing the roadway requires additional time.
- The crossing should occur as close to perpendicular (90 degrees) to the roadway as possible.
- It may be desirable to bring the path crossing up to a nearby signalized crossing is situations with high speeds/ADT and design and/or physical constraints.
- Signalized crossings may be necessary on trails with significant usage when intersecting with demanding roadways, but MUTCD warrants must be met for the installation of a signalized crossing.

Median Refuge Islands

Median refuge islands are barriers in the center portion of a street or roadway. When used in conjunction with mid-block or intersection crossings, they can be used as a crossing island to provide a place of refuge for bicyclists. They also provide opportunities for landscaping that in turn can help to slow traffic. Locations in Carrboro where crossing frequency is significant (such as Fayetteville Rd. at McDougle schools) and traffic volumes are not high are good candidates for a median refuge island.

- A center turn lane can be converted into a raised or lowered median thus increasing motorist safety.
- Median crossings should be at least 6-feet wide

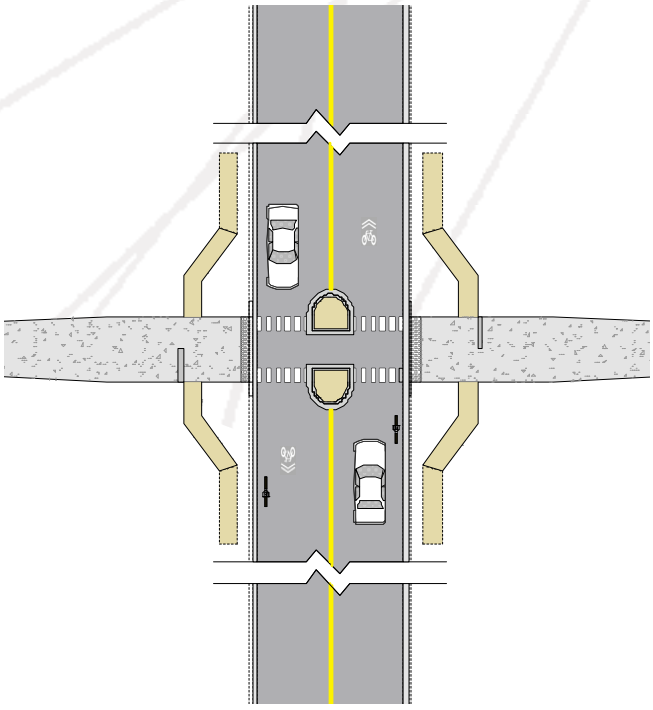


Fig. 7-23. Detail and photo showing Median Refuge with Shared Use Path and Sidewalks.

Fig. 7-24 — 7-25. Bollards can be used as a single (left) or in groups of three (far left) as seen here on several trails in Carrboro.

Bollards

Bollards are structures used to restrict access or improve security at the intersection of a roadway and a trail. While many bollards provide aesthetic benefits, typically, bollards are used to protect pedestrians and bicyclists from vehicles. Bollards are available in a variety of sizes, colors, materials, and finish options. Rubber is used to manufacturer flexible bollards, while plastic bollards are made of composite or recycled materials.

- Make bollards well marked and visible both day and night to bicyclists by using reflectors.
- Stationary bollards provide a constant barrier while retractable bollards permit authorized entry for emergency vehicles or maintenance
- Must be at least 3-feet tall, and at least 10-feet from the intersection
- Can be installed as a group or single; when using more than one bollard provide a 5-foot spacing to permit passage of bicycle trailers and tricycles
- Always use one or three bollards, never two, which can channel users to the center of the trail causing possible head-on collisions

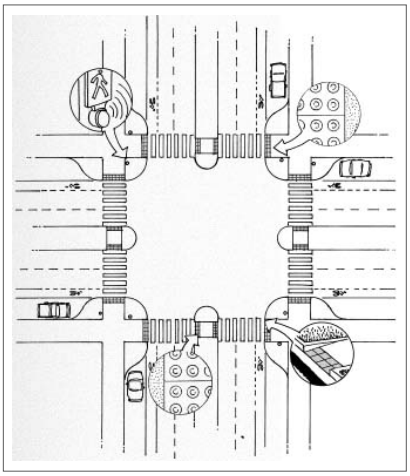


Fig. 7-26. FHWA diagram showing a well-designed intersection for bicyclist safety.

Fig. 7-27. A ladder-style crosswalk provides the most visibility for both the bicyclist and the motorist.

Marked Crosswalks

A marked crosswalk designates a pedestrian and bicyclist right-of-way across a street. It is often installed at controlled intersections or at key locations along the street (e.g., mid-block crossings) and in this Plan are prescribed for areas where bicycle corridor intersections occur. Marked crosswalks are important at intersections where bicyclists should dismount their bicycle and cross the roadway using the crosswalk. The use of crosswalks within the bicycle network is successful when used in conjunction with other traffic-calming devices to fully recognize low traffic speeds and enhance bicyclists' safety. A well-designed traffic calming location is not effective if bicyclists are using other unmodified and potentially dangerous locations to cross the street.

Marked crosswalks may be used under the following conditions: 1) At locations with stop signs or traffic signals, 2) At non-signalized street crossing locations in designated school zones, and 3) At non-signalized locations where engineering judgment dictates that the use of specifically designated crosswalks are desirable.

An engineering study may need to be performed to determine the appropriate width of a crosswalk at a given location, however marked crosswalks should not be less than six feet in width. In downtown areas or other locations of high pedestrian traffic, a width of ten feet or greater should be considered.

Guidelines:

- Should not be installed in an uncontrolled environment where speeds exceed 40 mph.
- Crosswalks alone may not be enough and should be used in conjunction with other measures to improve crossing safety, particularly on roads with average daily traffic (ADT) above 10,000.
- Width of marked crosswalk should be at least six feet wide; ideally ten feet or wider in Downtown areas.
- Curb ramps and other sloped areas should be fully contained within the markings.
- Crosswalk markings should extend the full length of the crossings.
- Crosswalk markings should be white per MUTCD.
- Ladder' patterns are recommended for intersection improvements in Carrboro for aesthetic and visibility purposes. Lines should be one to two feet wide and spaced one to five feet apart.

Fig. 7-28. Tucson, AZ, was the first to use the HAWK signal. (Photo courtesy of Tucson Department of Transportation)

*HAWK Signals**

High-intensity **A**ctivated cross**W**al**K** signals (or, HAWK signals) were developed by the City of Tucson, Arizona, as a means to increase pedestrian and bicyclist safety at crossings. HAWK signals are applied to intersections or mid-block crossings with low vehicular volumes where bicyclists and/or pedestrians have difficulty obtaining adequate gaps in major street traffic to safely cross the street. The signal features two overhead-mounted signal faces for each major street approach, with each face having two side-by-side circular red lenses above a circular yellow lens. These signal faces will rest in a dark condition until a bicyclist and/or pedestrian activates a control sequence. After flashing yellow and/or steady yellow change intervals, the red lenses will first display steady red, followed by a simultaneous (rather than wig-wag) flashing red display. The bicyclist then follows standard crossing signals with a countdown crossing signal and "do not cross" signal.

Tucson, AZ, has had much success with the installation of HAWK signals. According to the Safe Routes to School guide, the device substantially improves motorist stopping behavior, and the City has asked FHWA for approval in including the signal in the Manual for Uniform Traffic Control Devices (MUTCD). Portland, OR, is also experimenting with HAWK signals. The city has requested experimentation approval with the FHWA for the installation of these signals.

Carrboro should pilot the installation of several HAWK signals in areas where mid-block crossings or particularly sensitive crossing areas occur, such as S. Greensboro St. at the Harris Teeter, or Old Fayetteville Rd. in front of McDougle Schools.
For more information on the installation and design guidelines for HAWK signals, refer to Tucson's DOT website below:

http://www.dot.ci.tucson.az.us/traffic3/tspedestrian.php

**Considered to be innovative by the FHWA and NC-DOT; projects implementing this facility will require state and federal approval for permission to experiment with these types of treatments.*

Fig. 7-29. Signage can help instruct bicyclists on how to use the detector loop.

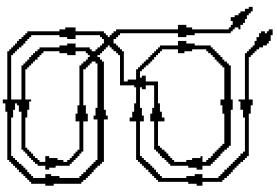
Bicycle-Activated Detector Loop

Changing how intersections operate can help make them more "friendly" to bicyclists. Improved traffic signal timing for bicyclists, bicycle-activated loop detectors, and camera detection make it easier and safer for cyclists to cross intersections. Bicycle-activated loop detectors are installed within the roadway to allow the weight of a bicycle to trigger a change in the traffic signal. This allows the cyclist to stay within the lane of travel and avoid maneuvering to the side of the road to trigger a push button, which ultimately provides extra green time before the light turns yellow to make it through the light. Current and future loops that are sensitive enough to detect bicycles should have pavement markings to instruct cyclists on how to trip them.

Loop detectors are important at cross streets, left-turn-only lanes and other travel lanes where cyclists may become stuck, unable to get a green light. Lane markings or signage that show cyclists where to position their bicycle maximize the capability of the sensor.

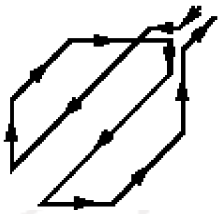
Quadruple Loop

- Detects most strongly in center
- Sharp cut-off sensitivity
- Used in bike lanes



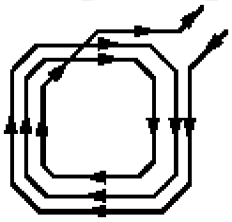
Diagonal Quadruple Loop

- Sensitive over whole area
- Sharp cut-off sensitivity
- Used in shared lanes



Standard Loop

- Detects most strongly over wires
- Gradual cut-off
- Used for advanced detection



From: Implementing Bicycle Improvements at the Local Level, FHWA, 1998, p. 70.

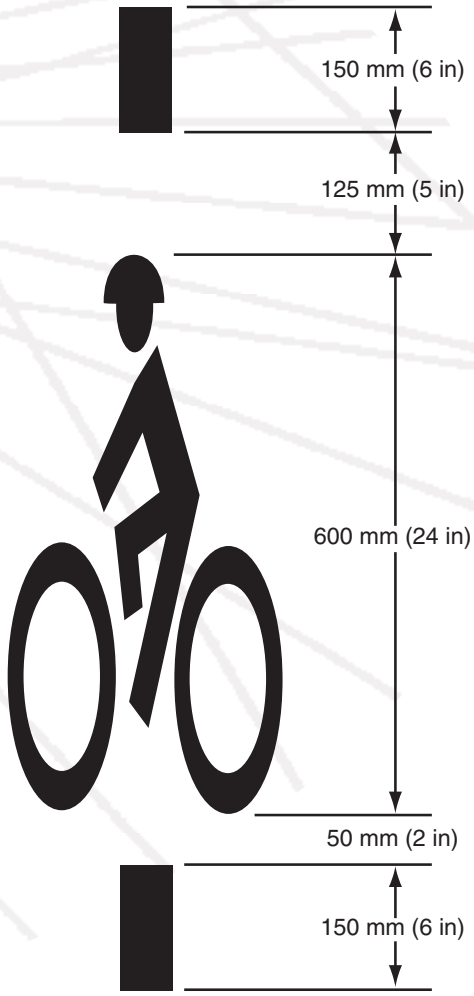


Fig. 7-30 — 7-31. Use pavement marking (top) to aid bicyclists in locating loop detectors at intersections (bottom).

Fig. 7-32 — 7-33. The PTA Bike Path intersection with Main St. and Jones Ferry Rd. could be a candidate for a bike signal (far left). A bicycle traffic signal used to bring bicycles leaving the UC-Davis campus back into the road network (left).

Bicycle-Specific Traffic Control Signals

A bicycle signal is an electrically powered traffic control device that may only be used in combination with an existing traffic signal. Bicycle signals direct bicyclists to take specific actions and may be used to address an identified safety or operational problem involving bicycles. A separate signal phase for bicycle movement will be used. Alternative means of handling conflicts between bicycles and motor vehicles shall be considered first. When bicycle traffic is controlled, green, yellow, or red bicycle symbols are used to direct bicycle movement at a signalized intersection. Bicycle signals shall only be used at locations that meet Department of Transportation Bicycle Signal Warrants. A bicycle signal may be considered for use only when the volume and collision, or volume and geometric warrants have been met:

1. *Volume*. When W = B x V and W > 50,000 and B >50.
   Where:
   W is the volume warrant.
   B is the number of bicycles at the peak hour entering the intersection.
   V is the number of vehicles at the peak hour entering the intersection.
   B and V shall use the same peak hour.

2. Collisions of types susceptible to correction by a bicycle signal have occurred over a 12-month period and the responsible public works official determines that a bicycle signal will reduce the number of collisions.

3. *Geometric.*
   (a) Where a separate bicycle/multi-use path intersects a roadway.
   (b) At other locations to facilitate a bicycle movement that is not permitted for a motor vehicle.

From: MUTCD 2003 and MUTCD 2003 California Supplement (May 20, 2004), Sections 4C.103 & 4D.104 - http://www/dot.ca.gov/hq/traffopps/signtech/mutcdsupp/

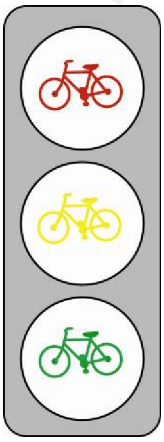


Fig. 7-34. Bicycle traffic signals.

Fig. 7-35. Bike box in England filled in with color to emphasize allocation of space to bicycle traffic.

Fig. 7-36. Bicycle box in Portland, OR.

*Bike Box/Advance Stop Line**

A bike box is a relatively simple innovation to improve turning movements for bicyclists without requiring cyclists to merge into traffic to reach the turn lane or use crosswalks as a pedestrian. The bike box is formed by pulling the stop line for vehicles back from the intersection, and adding a stop line for bicyclists immediately behind the crosswalk. When a traffic signal is red, bicyclists can move into this "box" ahead of the cars to make themselves more visible, or to move into a more comfortable position to make a turn. Bike boxes have been used in Cambridge, MA; Eugene, OR; Portland, OR; and European cities.

Potential Applications:

- At intersections with a high volume of bicycles and motor vehicles
- Where there are frequent turning conflict and/or intersections with a high percentage of turning movements by both bicyclists and motorists
- At intersections with no right turn on red (RTOR)
- At intersections with high bicycle crash rates
- On roads with bicycle lanes
- Can be combined with a bicycle signal (optional)
- Can be combined with a bicycle signal (optional)

Considerations:

- Bike boxes are not currently included in the MUTCD but there are provisions for jurisdictions to request permission to experiment with innovative treatments (and thus, with successful application, future inclusion of bike boxes in the MUTCD could occur).
- If a signal turns green as a cyclist is approaching an intersection, they should not use the bike box.
- Motorists will need to be educated to not encroach into the bike box.

**Considered to be innovative by the FHWA and NC-DOT; projects implementing this facility will require state and federal approval for permission to experiment with these types of treatments.*

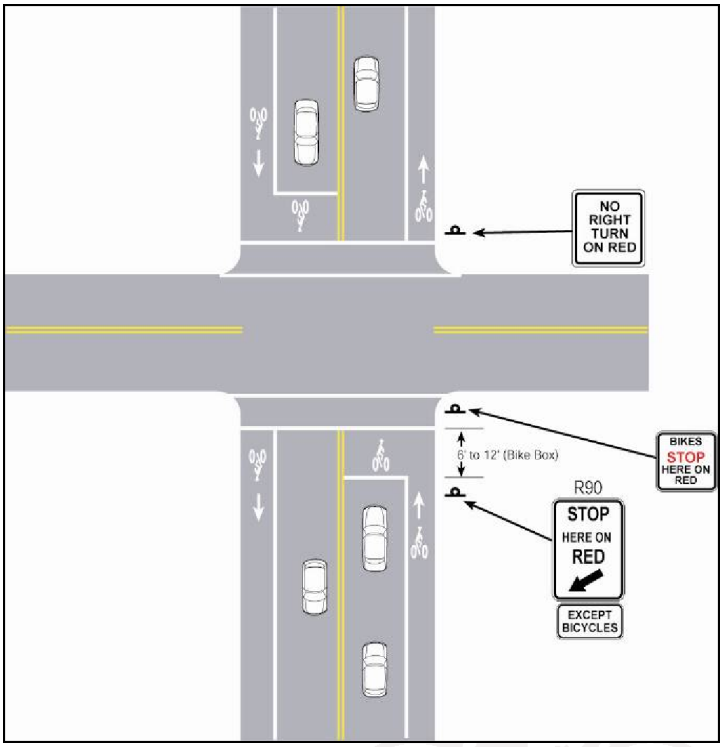


Fig. 7-38. Plan view of appropriate bicycle box configuration.

Fig. 7-37. Bicycle box being used in Portland, OR.

Bicycle Lane Development through Travel Lane Narrowing (Road Diet)

One means of developing bicycle lanes is through restriping or travel lane narrowing. In laying out the bicycle network facility recommendations and methods, it was determined that 10-foot travel lanes were acceptable in order to fit bicycle lanes into the existing roadway environment. For example, an existing five lane cross section with 12-foot lanes (Total roadway width of 60-feet) could be altered to 10-foot lanes with 5-foot bicycle lanes (Total roadway width of 60-feet). This methodology used in developing recommendations is supported by research in both automobile traffic safety and bicycle level of service improvements.

Current AASHTO literature, research, and precedent examples support the notion of reducing 12-foot travel lanes to 10-foot lanes. The 2004 AASHTO Green Book states that travel lanes between 10- and 12-feet are adequate for urban collectors and urban arterials.[1] "On interrupted-flow operating conditions at low speeds (45 mph or less), narrow lane widths are normally adequate and have some advantages." At the 2007 TRB Annual Meeting, a research paper using advanced statistical analysis, supported the AASHTO Green Book in providing flexibility for use of lane widths narrower than 12-feet on urban and suburban arterials. The paper indicates there is no difference in safety on streets with lanes ranging from 10-to 12-feet. "The research found no general indication that the use of lanes narrower than 12-feet on urban and suburban arterials increases crash frequencies. This finding suggests that geometric design policies should provide substantial flexibility for use of lane widths narrower than 12-feet." The research paper goes on to say "There are situations in which use of narrower lanes may provide benefits in traffic operations, pedestrian safety, and/or reduced interference with surrounding development, and may provide space for geometric features that enhance safety such as medians or turn lanes. The analysis results indicate narrow lanes can generally be used to obtain these benefits without compromising safety." and "Use of narrower lanes in appropriate locations can provide other benefits to users and the surrounding community including shorter pedestrian crossing distances and space for additional through lanes, auxiliary and turning lanes, bicycle lanes, buffer areas between travel lanes and sidewalks, and placement of roadside hardware."[2]

Precedent examples also show the large number of communities around the United States that have narrowed travel lanes to enable the development of bicycle lanes. The Missoula Institute for Sustainable Transportation accumulated a list of these communities by asking members of the Association of Pedestrian and Bicycle Professionals. The webpage titled "Accommodating Bike Lanes in Constrained Rights-of-Way (http://www.strans.org/travellanessurvey.htm) lists the community, their methods, and contact information. Cities such as Arlington, VA; Cincinnati, OH; Charlotte, NC; Houston, TX; and Portland, OR have regularly narrowed travel lanes to 10-feet or even commonly

1 American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, Washington, DC 2004.

2 Relationship of Lane Width to Safety for Urban and Suburban Arterials, Ingrid B. Potts, Harwood, D., Richard, K, TRB 2007 Annual Meeting

use them in new roadway development. Arlington, VA has been installing bicycle lanes on streets when they are repaved and have a number of streets with 10-foot lanes and bicycle lanes that have been functioning well without operational issues and complaints. Cincinnati, OH uses a policy that 10-foot lanes on collections and arterials are always permitted. New installations of 10-foot lanes with bicycle lanes require a speed limit of 35 mph or under. By restriping 12-foot lanes to 10-feet, the City of Houston, TX has converted 30 miles of arterial streets.

Lane narrowing and the addition of bicycle lanes will require further analysis beyond this planning effort. Changing the roadway design may also require a reduction in speed limit and consideration of traffic calming designs such as median islands. For roadways with higher speed limits and traffic volumes, wider bicycle lanes may be warranted. Further analysis of bicycle lane restriping projects is warranted to determine appropriateness of lane narrowing, bicycle lane widths, and speed limits that impact both motorists and bicyclists.

Fig. 7-39 — 7-40. Colored bike lanes in Vancouver, B.C. (left) and New York City (right).

*Colored Bike Lanes**

European countries as well as the City of Portland, OR, and Brooklyn, NY, have experimented with blue and green bike lanes and supportive signing with favorable results. Studies after implementation showed more motorists slowing or stopping at the blue lanes and more motorists using their turn signals near the colored lanes.

- Green is the recommended color (some cities that have used blue are changing to green, since blue is associated with handicapped facilities).
- Jurisdictions must obtain federal approval before experiementing with colored bicycle lanes.

**Considered to be innovative by the FHWA and NC-DOT; projects implementing this facility will require state and federal approval for permission to experiment with these types of treatments.*

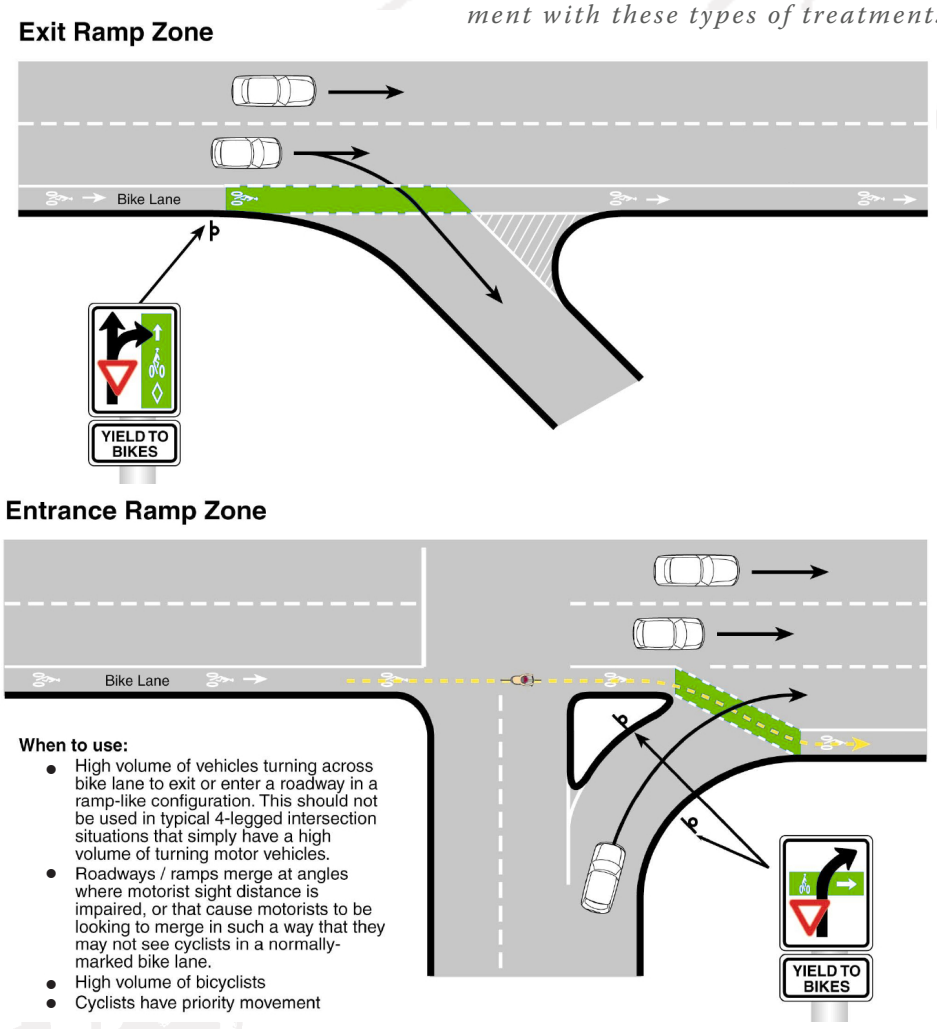


Fig. 7-41. Colored bicycle lane treatment through conflict area.

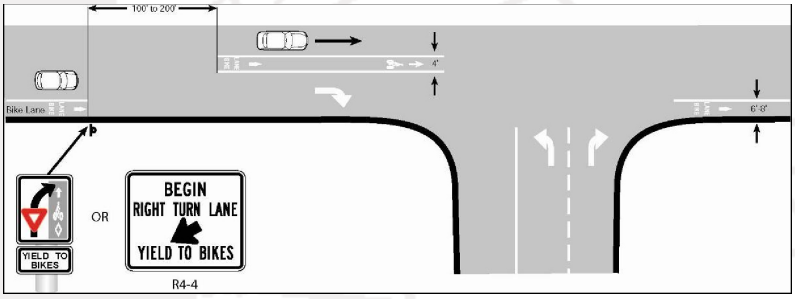


Fig. 7-42. Bicycle lane adjacent to a right turn only lane.

Typical Right Turn-Bicycle Lane Configurations

Common bicyclist/motorist collisions occur within the blind spot of the motorist. When turning right, motorists forget to yield to bicycles or do not see them approaching. (Note: the following diagrams are from Caltrans, thus there is a discrepancy with what is recommended in this Plan regarding bike lane widths. Use the diagrams for conceptual purposes only.)

- Bike Lane Through 'Right Turn Island' Intersections (Fig. 7-43)
- Shared Travel Lane Through 'Right Turn Island' Intersection (Fig. 7-43)
- Bicycle Lane Adjacent to a 'Right Turn Only' Lane (Fig. 7-42 & 7-45)
- Bicycle Lane through a freeway ramp (Fig. 7-44 & 7-46)

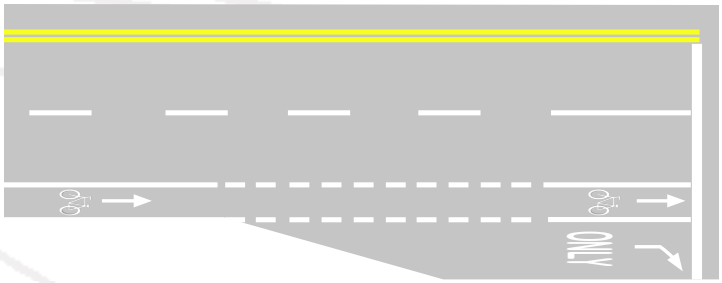


Fig. 7-45. Bicycle Lane Adjacent to a 'Right Turn Only' Lane

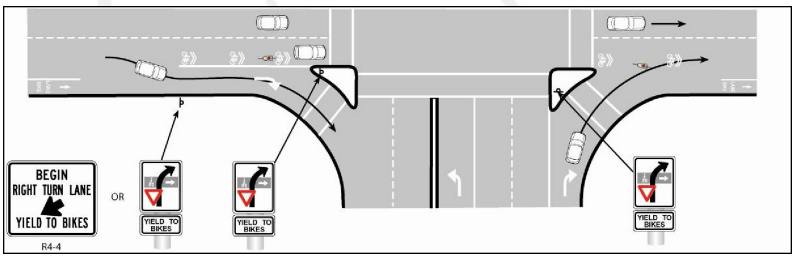


Fig. 7-43. Shared travel lane through right turn island intersection with exclusive right turn lanes.

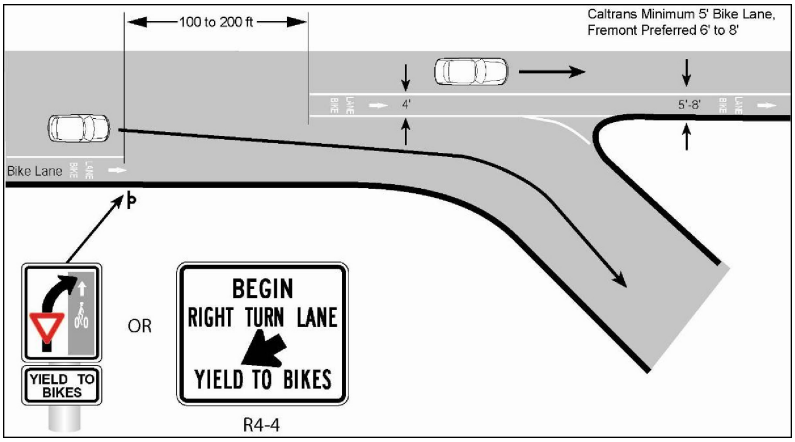


Fig. 7-44. Bicycle lane through a freeway ramp.

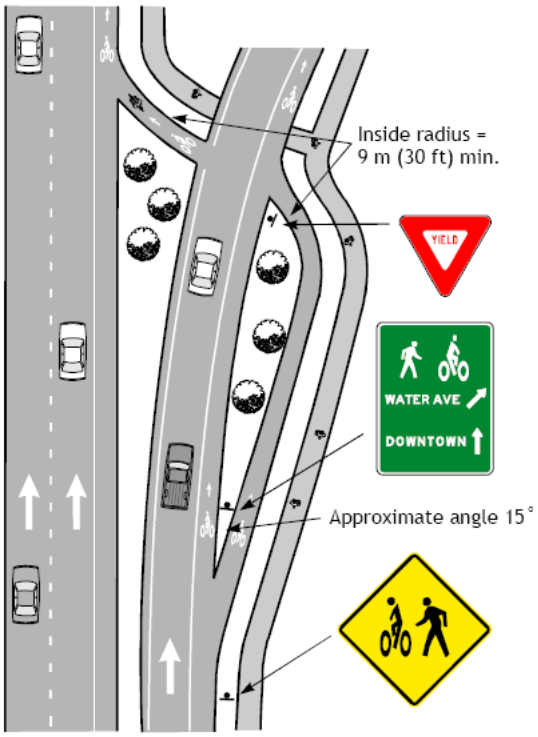


Fig. 7-46. Bicycle Lane Configuration at Exit Ramp (from the Oregon Bicycle and Pedestrian Plan)

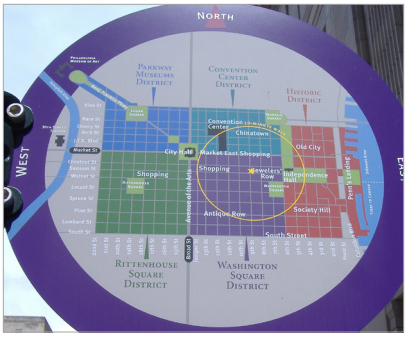


Fig. 7-47 — 7-49. Some national examples of high-quality wayfinding include those in Centre City Philadelphia (far left), the City of Greenville, SC (center/left), and Grand Forks Greeway, ND (left).

7.5 Bicycle Signage

A comprehensive system of signage ensures that information is provided regarding the safe and appropriate use of all facilities, both on-road and on greenways. The bicycle network should be signed seamlessly with other alternative transportation routes, such as bicycle routes from neighboring jurisdictions, trails, historic and/or cultural walking tours, and wherever possible, local transit systems.

Signage includes post- or pole-mounted signs or kiosks. Signage is further divided into information signs, directional/wayfinding signs, regulatory signs and warning signs. Trail signage should conform to the (2009) *Manual on Uniform Traffic Control Devices* and the *American Association of State Highway Transportation Official Guide for the Development of Bicycle Facilities*. Bicycle signage should also be coordinated with the Town of Carrboro's current signage standards.

Directional Signage

Implementing a well-planned and attractive system of signing can greatly enhance bikeway facilities by signaling their presence and location to both motorists and existing or potential bicycle users. Effective directional signage can encourage more bicycling by leading people to town bike paths, or bike routes and by creating a safe and efficient transportation option for local residents and visitors.

The signage examples in Figure 7-50 show a number of different signs and markings, both on poles and on the roadway, that the City of Portland, OR has adopted for their new bicycle signage program. The signs have been approved by the Oregon DOT, and will be installed throughout Portland in the near future. Wayfinding signs such as these improve the clarity of travel direction while illustrating that destinations are only a short ride away. The signs shown are provided only as a point of reference for the purposes of these guidelines only.

Conventional bicycle route signage examples, shown in Figure 7-51, help bicyclists find the most comfortable route through town via bicycle. Roadways with bicycle route signage generally have less traffic, more negotiable terrain, and are safe to travel on by bike. Signed bike routes are usually available on local bicycle maps to help the bicyclist plan his or her route accordingly. Bicycle route signage should be repeated at regular intervals so that bicyclists entering from side streets will have an opportunity to realize the presence of the route.

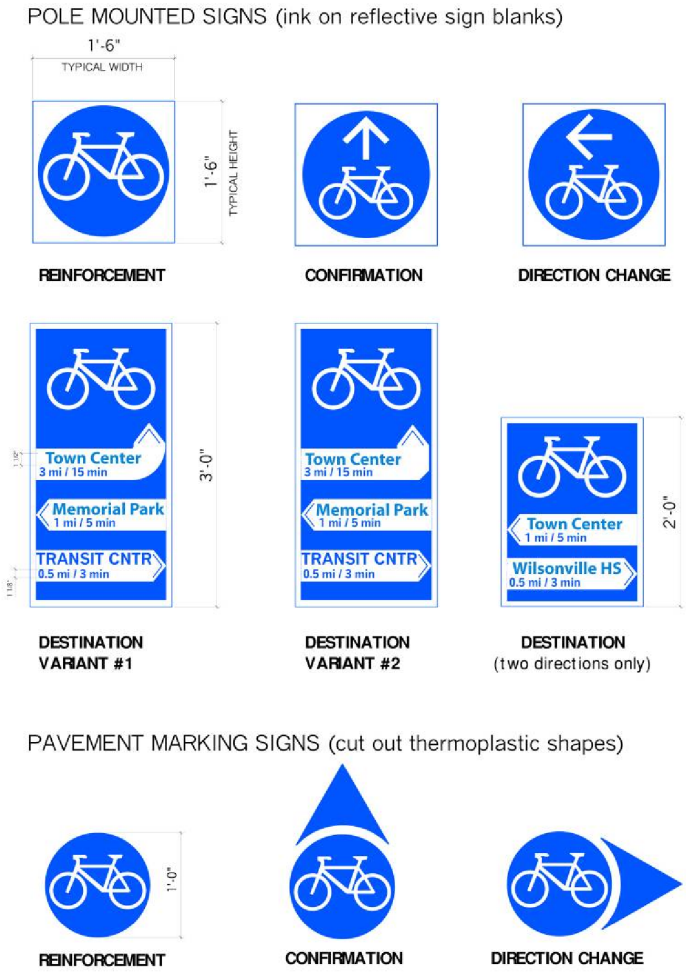


Fig. 7-50. Innovative On-Road Facilities Signage used in Portland, OR which could be used experimentally in Carrboro.

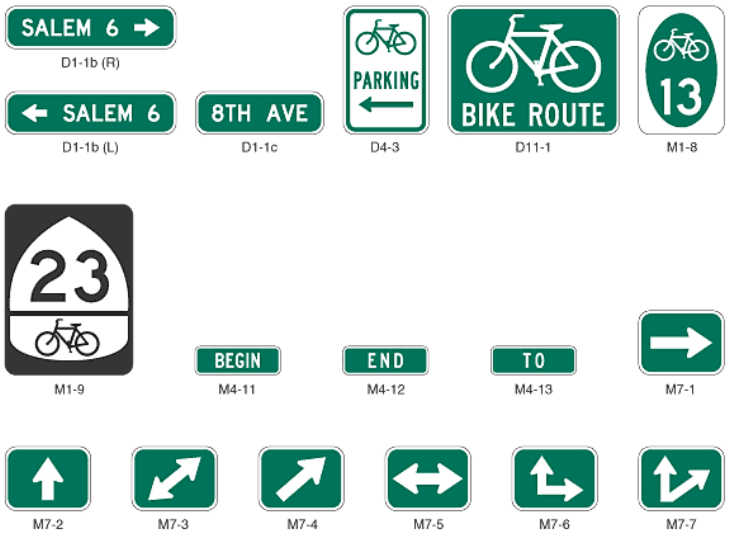


Fig. 7-51. Bicycle Route Guide signs which are approved by NCDOT.

Fig. 7-52. Existing bicycle regulatory signage as well as traffic calming signage in Carrboro.

Regulatory/Warning Signage

Regulatory and warning bicycle signage should conform to the Manual on Uniform Traffic Control Devices (MUTCD). The examples shown in Figure 7-53 are regulatory signs for bicycle (their labels are sign reference numbers for the MUTCD).

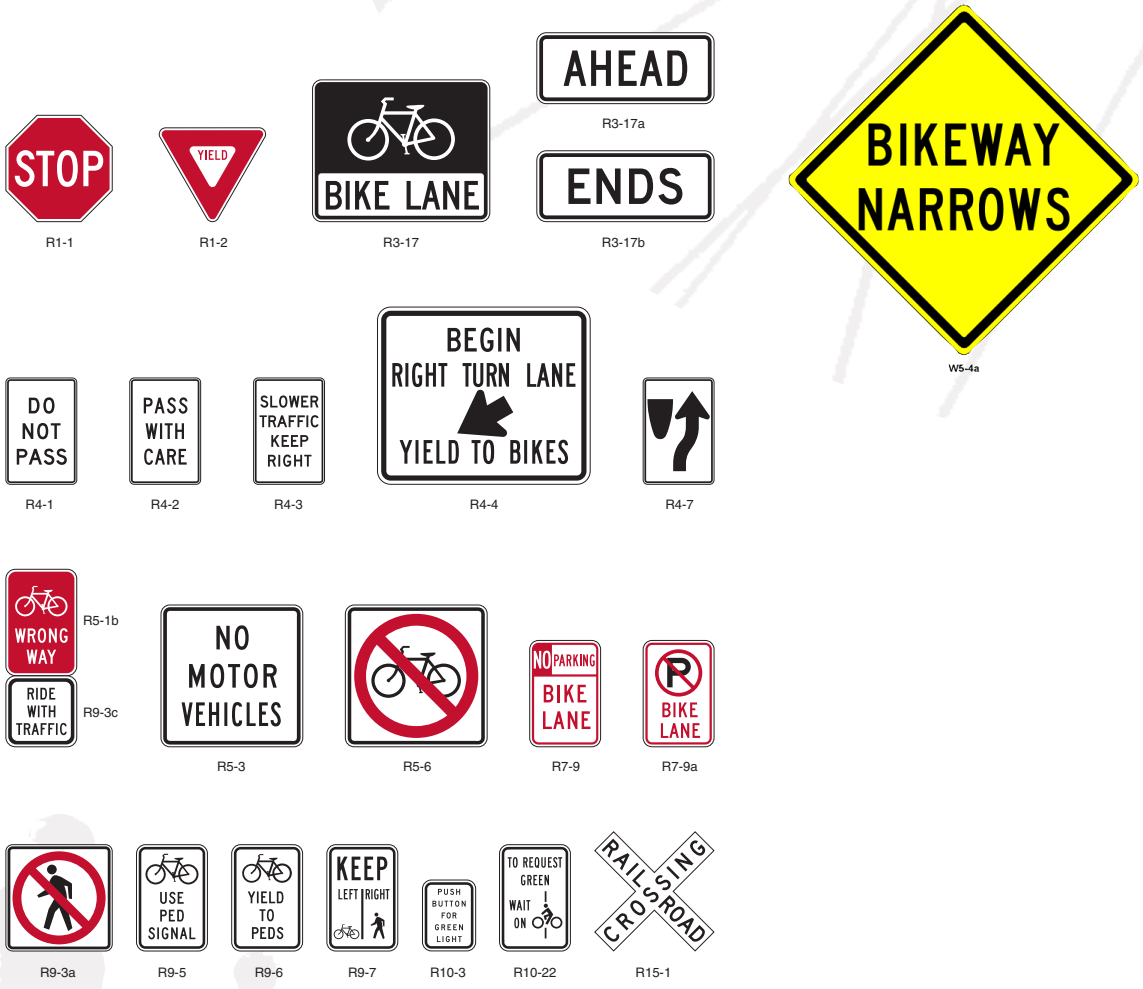


Fig. 7-53. Bicycle signage options from the MUTCD.

Fig. 7-54. Share the Road signs remind motorists that bicyclists have the right to ride on the roadway.

Fig. 7-55. The "Bikes Allowed Use of Full Lane" sign is currently used on an experimental basis in cities such as San Francisco, CA.

Special Purpose Signage

The "Share the Road" sign Fig. 7-54, is designed to advise motorists that bicyclists are allowed to share and have the right to cycle on narrow roadways with motor vehicles. For more on the "Share the Road Initiative" go to: http://ncdot.org/transit/bicycle/safety/programs_initiatives/share.html

Innovative signage is often developed to increase bicycle awareness and improve visibility (such as "Bikes Allowed Use of Full Lane", (Fig. 7-55). Special purpose signs to be installed on public roadways in North Carolina must be approved by NCDOT's Traffic Control Devices Committee and/or the Town of Carrboro. New designs can be utilized on an experimental basis with NCDOT approval.

Where bicycle facilities terminate or the roadway narrows and cannot accomodate bicycle facilities, signage should be used in Carrboro to remind motorists and bicyclists to resume sharing a travel lane. This type of sign is currently being used in the Town of Chapel Hill (Fig. 7-56).

Fig. 7-56. Where bicycle facilties end, as seen on MLK Blvd. in Chapel Hill, the above signage could be used to remind bicyclists and motorists to resume sharing the travel lane.

Fig. 7-57. Bicycle parking wayfinding signage will inform the bicyclist about where facilities exist.

Fig. 7-58. An example of a covered bicycle parking facility.

7.6 Ancillary Features

Bicycle Parking

As more bikeways are constructed and bicycle usage grows, the need for bike parking will climb. Long-term bicycle parking at bus stops and work sites, as well as short-term parking at shopping centers and similar sites, can support bicycling. In addition to providing the venue for parking, bicycle parking wayfinding signage will help provide direction to the facilities. Bicyclists have a significant need for secure long-term parking because bicycles parked for longer periods are more exposed to weather and theft, although adequate long-term parking rarely meets demand.

When choosing bike racks, there are a number of things to keep in mind:

- The rack element (part of the rack that supports the bike) should keep the bike upright by supporting the frame in two places allowing one or both wheels to be secured.
- Install racks so there is enough room between adjacent parked bicycles. If it becomes too difficult for a bicyclist to easily lock their bicycle, they may park it elsewhere and the bicycle capacity is lowered. A row of inverted "U"racks should be installed with 15 inches minimum between racks.
- The inverted "U" shaped bicycle racks are preferential for short term parking due to their efficient use of space, ease of use and security, while bicycle lockers provide a safe and secure option for long term bicycle parking (Figure 7-61).
- Empty racks should not pose a tripping hazard for visually impaired pedestrians. Position racks out of the walkway's clear zone.
- When possible, racks should be in a covered area protected from the elements. Long-term parking should always be protected (Figure 7-58).
- For safety and visibility, provide lighting in bicycle parking areas through overhead or bollard lighting fixtures.

For more information on bicycle parking facilities please visit:

http://www.apbp.org/pdfsanddocs/Resources/Bicycle%20Parking%20Guidelines.pdf

http://www.ibike.org/engineering/parking.htm

Fig. 7-59. Bicycle parking in downtown Carrboro.

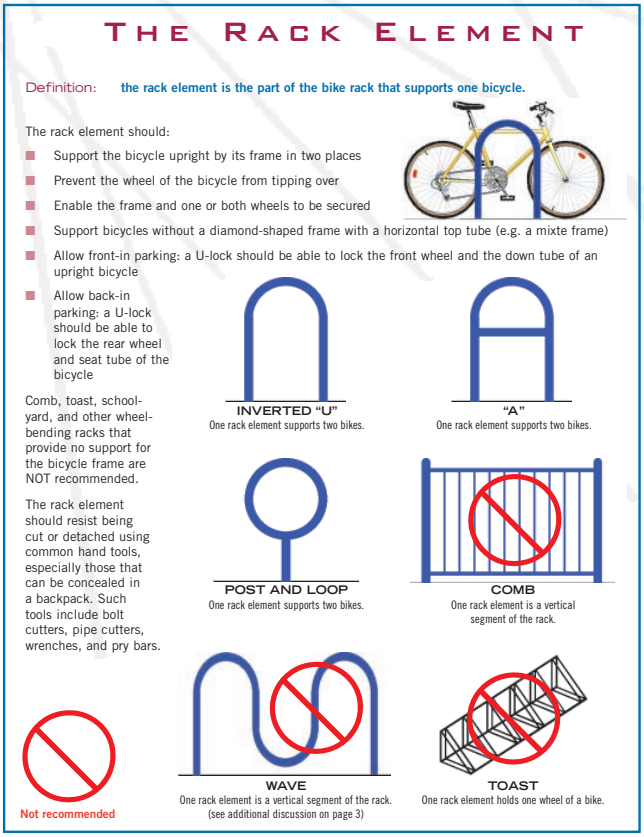


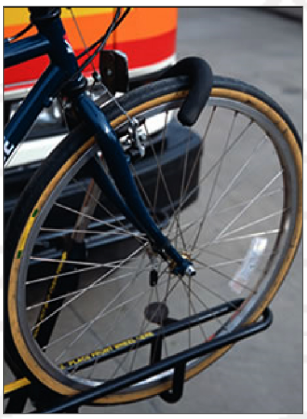
Fig. 7-60. Recommended bicycle parking facilities, Source: APBP. (www.apbp.org)

Bicycle Storage

Bicycle lockers are a crucial component of the bicycle system. They offer safe and secure storage at transit centers and destinations. Parking rates are reasonable at about 3-5 cents per hour. Bicycle lockers are designed to be secure and flexible so that the individual bikes with panniers, computers, lights, etc. can be left on the bike. Some designs of bike lockers can be stacked so there is twice the parking density. Good protection from the weather is another benefit. Bike lockers tend to be used most for long term bicycle commuter parking in area without a lot of continuous oversight. Carrboro's future mixed-use developments (which may include residential use) would benefit from these types of storage facilities.

Fig. 7-61. Bicycle locker facility and pay stations offer long-term parking.

Fig. 7-62. Chapel Hill Transit, serving parts of Carrboro, provides racks on the front of their buses.



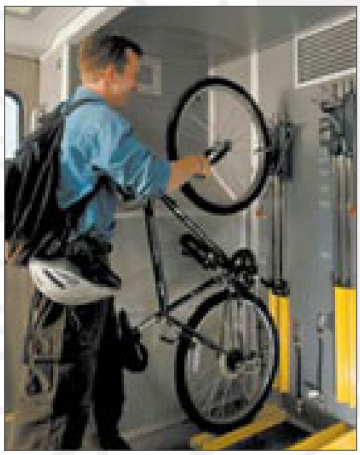
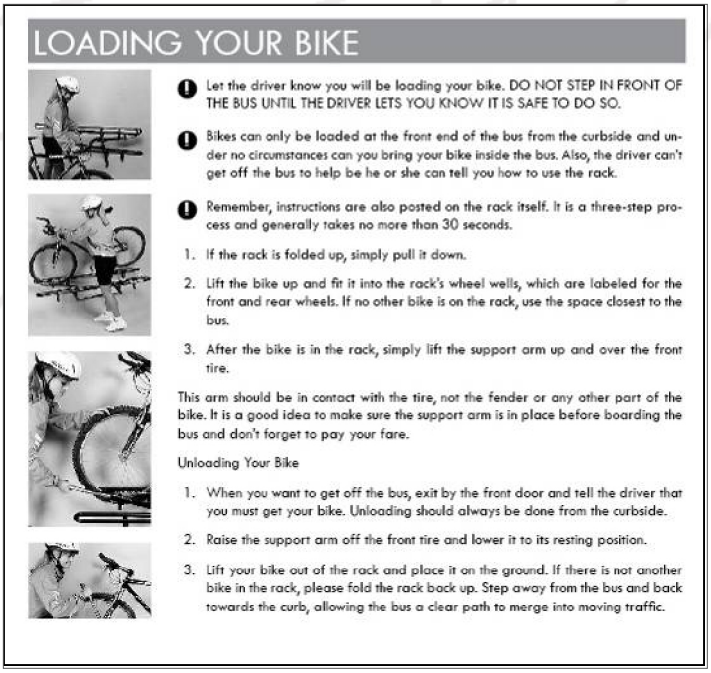


Fig. 7-63. Examples of integrating bicycle facilities with transit modes.

Bicycle Facilities on Buses

Integrating bicycle facilities with transit modes allows bicyclists to greatly expand their range of travel or "trip chain". Integration of facilities with transit modes allows cyclists to use their bicycles on one or both ends of their daily commute, allowing greater flexibility. Figure 7-63 shows examples of commuter bus services with customized facilities allowing for simple and secure storage of bicycles without hindering or impeding other passengers. Chapel Hill Transit buses, serving parts of Carrboro, provide racks on the front and should maintain or expand this service to bicyclists.



LOADING YOUR BIKE

- Let the driver know you will be loading your bike. DO NOT STEP IN FRONT OF THE BUS UNTIL THE DRIVER LETS YOU KNOW IT IS SAFE TO DO SO.
- Bikes can only be loaded at the front end of the bus from the curbside and under no circumstances can you bring your bike inside the bus. Also, the driver can't get off the bus to help be he or she can tell you how to use the rack.
- Remember, instructions are also posted on the rack itself. It is a three-step process and generally takes no more than 30 seconds.

1. If the rack is folded up, simply pull it down.
2. Lift the bike up and fit it into the rack's wheel wells, which are labeled for the front and rear wheels. If no other bike is on the rack, use the space closest to the bus.
3. After the bike is in the rack, simply lift the support arm up and over the front tire.

This arm should be in contact with the tire, not the fender or any other part of the bike. It is a good idea to make sure the support arm is in place before boarding the bus and don't forget to pay your fare.

Unloading Your Bike

1. When you want to get off the bus, exit by the front door and tell the driver that you must get your bike. Unloading should always be done from the curbside.
2. Raise the support arm off the front tire and lower it to its resting position.
3. Lift your bike out of the rack and place it on the ground. If there is not another bike in the rack, please fold the rack back up. Step away from the bus and back towards the curb, allowing the bus a clear path to merge into moving traffic.

Fig. 7-65. Instructions on how to load a bicycle onto a bus equipped with a bicycle rack, developed for a bicycle user map by Fremont, CA.

Affordable and Accessible Bicycle Maintenance

This bicycle repair stand shown in Figure 7-64 is a fixture within the Cambridge, UK, town marketplace. The Carrboro equivalent would be at the farmers' market which is a center for activity, easily accessible by foot or bicycle. Local bike shops in Carrboro could provide similar services. The presence of smaller-scale operations that primarily provide maintenance and repair functions within semi-permanent structures like the tent and tarp shown below allowing for a lower cost operation, thereby passing on savings to the customer in terms of lower repair and maintenance costs.

Fig 7-64. A bicycle maintenance stands in the UK.

Fig. 7-66. Bicycle-friendly drainage grate.

Fig. 7-67. Dangerous drainage grate condition; this example is dangerous due to the surrounding paving condition (when the road was resurfaced the drainage grate remained at the same height).

Bicycle-Friendly Drainage Grates

Drainage grates usually occupy portions of roadways, such as bicycle lanes, where bicycles frequently travel. Often drainage grates are poorly maintained or are of a design that can damage a bicycle wheel or in severe circumstances, cause a bicyclist to crash. Improper drainage grates create an unfriendly obstacle a cyclist must navigate around, often forcing entrance into a motor vehicle lane in severe cases. Bicycle-friendly drainage grates should be installed in all new roadway projects and problem grates should be identified and replaced.

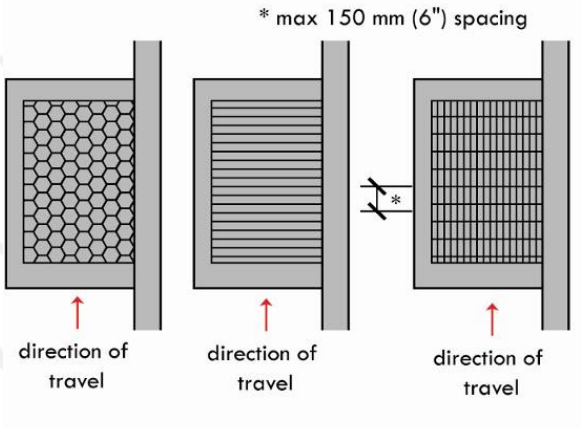


Fig. 7-69. Bicycle Friendly Drainage Grate Designs.

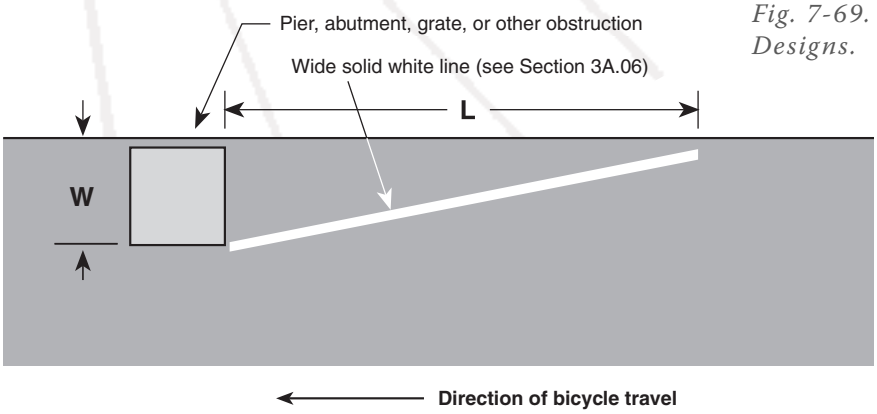


Fig. 7-68. MUTCD example of obstruction pavement marking; if dangerous drainage grates (or other obstructions) are not to be fixed in the short term, then this pavement marking should direct cyclists away from the obstruction.

Fig. 7-70. Bicycle-friendly drainage grate in Carrboro.

Bicycle Facilities at Rail Road Crossings

Railroad crossings are particularly hazardous to those who rely on wheeled devices for mobility (railroad crossings have flangeway gaps that allow passage of the wheels of the train, but also have the potential to catch wheelchair casters and bicycle tires). In addition, rails or ties that are not embedded in the travel surface create a tripping hazard. Recommendations:

- Make the Crossing Level: Raise approaches to the tracks and the area between the tracks to the level of the top of the rail.

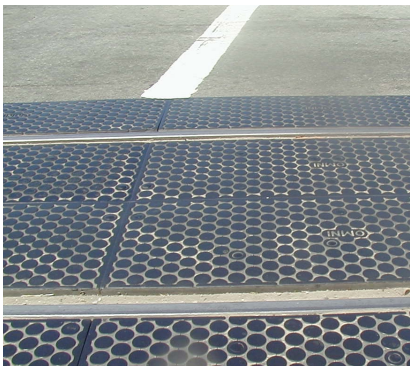


Fig. 7-71. Installing a rubber surface rather than asphalt around railroad flangeways reduces changes in level and other maintenance problems.

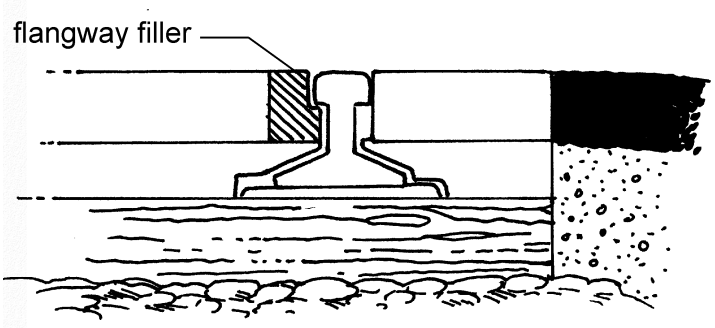
- Bikes Should Cross RR at Right Angle

- When bikeways or roadways cross railroad tracks at grade, the roadway should ideally be at a right angle to the rails. When the angle of the roadway to the rails is increasingly severe, the approach recommended by Caltrans (Highway Design Manual, Section 1003.6) and AASHTO (Guide for the Development of Bicycle Facilities, 1999, p.60) is to widen the approach roadway shoulder or bicycle facility, allowing bicycles to cross the tracks at a right angle without veering into the path of passing motor vehicle traffic.

- Use Multiple Forms of Warning: Provide railroad crossing information in multiple formats, including signs, flashing lights, and audible sounds.

- Clear Debris Regularly: Perform regular maintenance to clear debris from shoulder areas at railroad crossings.

- Fill Flangeway with Rubberized Material or Concrete Slab: Normal use of rail facilities causes buckling of paved-and-timbered rail crossings. Pavement buckling can be reduced or eliminated by filling the flangeway with rubberized material, concrete slab, or other treatments. A beneficial effect of this is a decrease in long-term maintenance costs.



Railings

Railings are important features on bridges, some boardwalks, or in areas where there may be a hazardous drop-off.

- At a minimum, railings should consist of a vertical top, bottom, and middle rail. Picket-style fencing should be avoided as it presents a safety hazard for bicyclists
- A pedestrian railing should be 42-inches above the surface.
- A bicyclist railing should be 54-inches above the surface.
- The middle railing functions as a "rub rail" for bicyclists and should be located 33-and 36-inches above the surface.
- Local, state, and/or federal regulations and building codes should be consulted to determine when it is appropriate to install a railing.

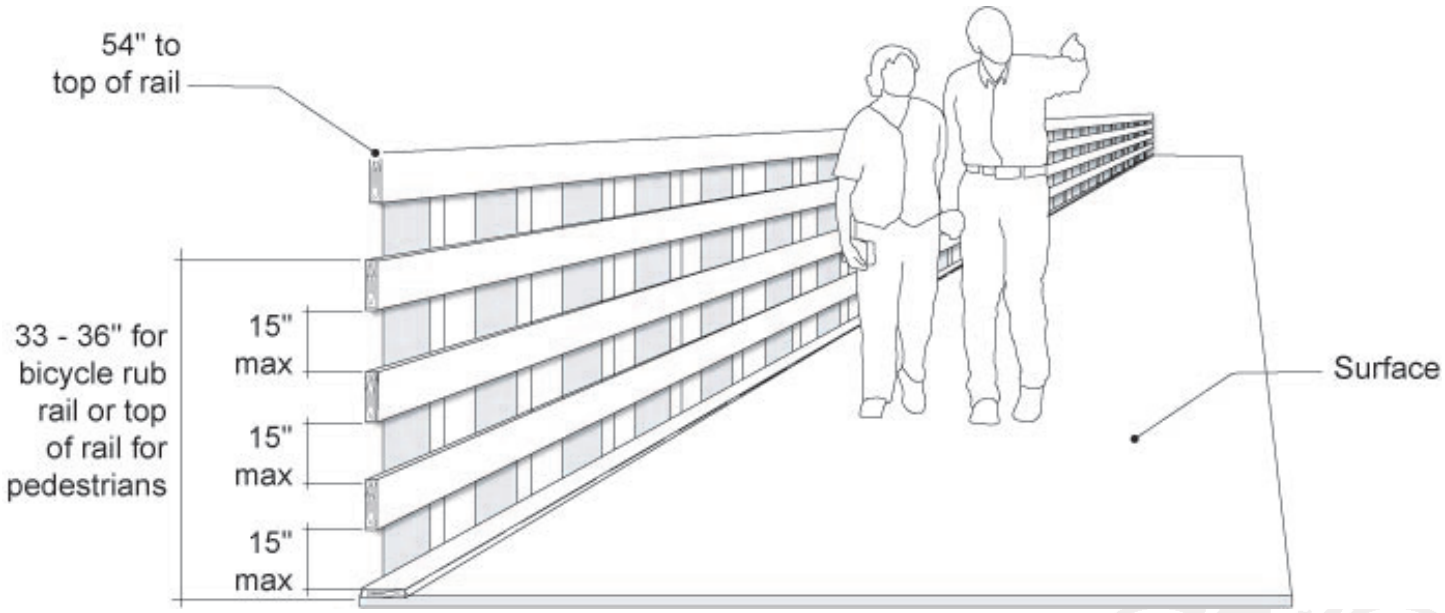


Fig. 7-72 — 7-73. Repaving and restriping so that bike lanes are smooth and visible will make facilities more comfortable for bicyclists as indicated in the top photo; manholes and drainage grates should be properly located within the bikeway to avoid swerving bicyclists, bicycle accidents, or negligence of the facilities.

Bicycle Facility Maintenance

The regular maintenance of on-road bicycle facilities and off road bike trails is critical to their overall functionality and safety for users. A cyclist who must swerve in order to miss a pothole or debris risks getting hit by passing automobiles. Several comments were received from the public regarding the maintenance of facilities during the planning process.

Below is a collection of comments received regarding bicycle-related maintenance issues in Carrboro. For more public input comments, see Appendix B: Public Input.

- "Sweep the bike lanes and shoulders more frequently, especially on Homestead Rd.; gravel and debris get pushed into the paved shoulder."

- "Improve potholes and road surface conditions on sides of road, especially near Carr Mill Mall and on Main St. near the BP station."

- "Railroad crossing at Main St. has deep ruts next to tracks."

- "Manholes, grates, and other utilities need a smoother surface transition within the bicycle facility."

Fig. 7-74. This example of a well designed utility condition in the roadway (taken in Carrboro), provides a curb cut for the manhole cover so that it does not interfere with the bicycle right-of-way.

Bicycle Facility Maintenance (continued)

Bicycle facilities provided within the roadway right-of-way should be maintained by either NCDOT or the Town of Carrboro Public Works Department. A Carrboro staff member should be designated as the main contact for the maintenance of bicycle facilities in the roadway right-of-way. This staff member should coordinate with the appropriate departments to set up a free maintenance hotline and conduct maintenance activities in the field. Funding for an ongoing maintenance program should be included in the Town's operating budget.

Note that the schedule shown on Table 7-1 is intended to provide general guidance for routine and remedial maintenance activities. The frequency of bicycle facility maintenance within the roadway right-of-way will vary. Maintenance needs will depend upon many factors, including pavement surface type, the use of paint or thermoplastic for markings, and traffic volumes. The Town of Carrboro Public Works Department and NCDOT should make immediate repairs to any on-road bicycle facilities that are damaged or have hazardous conditions.

Maintenance of Bicycle Facilities within the Roadway Rights-of-Way

Task	Frequency	Comments
Regular inspection	2 times per year	Includes all on-road bikeways, identify needed repairs of pavement signs, markings, etc
Shoulder and bike lane sweeping	2 times per year	All roadways with bicycle facilities
Shoulder and bike lane repairs	As needed	Repair of road surface, including potholes, cracks, or other problems on bicycle facilities
Median island and curb extension repairs	As needed	Repair of curb and gutters, removal of debris
Shoulder and bike lane resurfacing	During regular roadway repaving	Ensure that pavement width is maintained or increased during repaving projects
Debris removal from shoulders	As needed	Remove debris from roadway shoulders and bike lanes such as limbs, silt, and broken glass
Signs and markings	As needed	Repair or replace pedestrian and bicycle warning signs, bicycle route signs, crosswalk markings, bicycle lane markings, and any other similar facilities identified during inspections
Vegetation control	During regular roadway maintenance	Mow grass and trim limbs and shrubs 2 feet back from sidewalk edge
Litter removal	6 times per year	Could be done with volunteers

Table 7-1. Bicycle facility maintenance chart presents tasks and necessary frequency of tasks.