Tech Brief

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TRAFFIC CONTROL STRATEGIES FOR CONCRETE PAVEMENT REHABILITATION AND RECONSTRUCTION

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INTRODUCTION

The rehabilitation and reconstruction of existing highway pavements require the optimization of the construction operations. One important aspect of this is to provide defined and controlled traffic patterns that ensure the safety of both the traveling public and the work crews. Effective work zone traffic management (WZTM) is a critical part of any rehabilitation or reconstruction project that is performed under active traffic, and involves the assessment of work zone impacts and the development of strategies for mitigating those impacts. Some of the key reasons for implementing effective WZTM practices include (Harrington and Fick 2014):

- **Safety**: Ensure the safety of construction workers, the traveling public, and minimize the impact on emergency responders.
- **User Delay Costs**: Minimize traffic delays by scheduling suitable work windows or designing appropriate detours.
- **Access**: Maintain access to key businesses and residential areas.
- **Construction Quality, Cost, Productivity, and Schedule**: Ensure timely completion of roadwork at the lowest practical cost without compromising quality and safety.
- **Pavement Performance**: Construct smooth, durable, long-lasting pavements.
- **Environmental Sustainability**: Minimize impacts on vehicle fuel economy by ensuring smooth flow of traffic.

Work Zone Operations Best Practices Guidebook (FHWA 2013) provides a compilation of work zone operations best practices used and recommended by various State and local agencies in the U.S.

This Tech Brief provides an overview on work zone traffic management fundamentals and provides recommended traffic management strategies specific to concrete pavement rehabilitation and reconstruction. It also presents example traffic control and management strategies for concrete pavements, noting that these are used to illustrate the concepts but should be tempered based on local traffic control regulations and requirements.

ELEMENTS OF TRAFFIC MANAGEMENT

In construction work zones, there are two primary considerations: (a) how to handle or manage the traffic that operates through the work zone, and (b) the techniques to be used to accomplish that traffic management. Although there are a number of other considerations, the most appropriate strategy is selected by balancing trade-offs between safety, project cost, societal considerations, and traffic management. Once specific strategies have been selected, they are documented in formal traffic management plans (ACPA 2000; CFR 2017).

This section describes some of the basic principles of traffic management and describes various work zone types that may be used to meet specific conditions. It also presents general considerations for work zone safety.

Principles

The fundamental principles of WZTM are discussed in Section 6B of Part VI of the *Manual on Uniform Traffic Control Devices [MUTCD]* (FHWA 2009). These principles provide both a starting point for the consideration of a suitable traffic control strategy and a checklist of other issues that should be considered. The key principles include the following (FHWA 2009):

- General plans or guidelines should be developed to provide safety for motorists, bicyclists, pedestrians, workers, enforcement/emergency officials, and equipment.
- Road user movement should be inhibited as little as practical.
- Motorists, bicyclists, and pedestrians should be guided in a clear and positive manner when approaching and traversing work zones.
- Routine inspections of work zone traffic control elements should be performed.
- Roadside safety should be maintained during the life of the work zone.
- Appropriate training related to job decisions should be provided to each person involved in the work zone.
- Good public relations should be maintained.

Additional details on these principles are available in the MUTCD (FHWA 2009).

Work Zone Types

"Work zone type" refers to the basic layout of the work zone at the construction job site. Figure 1 presents eight basic work zone types along with illustrations of each. Figure 2 provides general guidelines for the selection of the work zone type, based on the facility type and other factors (IDOT 2016).

Work Zone Safety Considerations

In establishing work zones, the safety of both the users and the workers must be given a top priority. As a minimum, the work zone safety plan must address the following (ACPA 2000):

- **Traffic management strategies**. Use a strategy that enables work to be completed as quickly and efficiently as possible. In improving work zones, Interstate highways and other freeways should receive particular consideration since these roadways experience higher traffic volumes.
- **Crashes**. Crashes in work zones can significantly reduce capacity and traffic flow speed. Appropriate strategies should be established to manage crashes in work zones and restore traffic operations as quickly as possible.
- **Nighttime closures**. Work zones should be critically inspected to ensure that they include adequate guidance for motorists during nighttime travel. Items to consider when improving nighttime work zones include shorter spacing of channelizing devices, longer transition lengths, changing colors near off-ramps, widening pavement markings, deployment of more truck-mounted attenuators, and use of real-time information signs and changeable message signs.
- **Larger trucks**. Special attention should be given to accommodate tractor-trailer combinations in work zones and transitions. Issues to consider include lane widths in curves with runs of barrier on both sides, the provision of adequate stopping distance when congestion is expected, and evaluating the availability of potential detours.
- **Workers on foot and equipment operators**. Recommendations for improving the safety of workers include minimizing contact between workers on foot and highway traffic, improving worker visibility, developing traffic plans to address movement of workers and work vehicles, providing training to workers and allowing only trained personnel on job site, and performing regular inspections of work zone traffic control elements.
- **Pedestrians**. Items to accommodate pedestrians include separating pedestrians from vehicles and equipment, providing positive protection systems (e.g., barriers, walkways), using clear language on signs, avoiding circuitous routes, and maintaining unimpeded and smooth pathways with adequate width, lighting, and visibility of traffic.

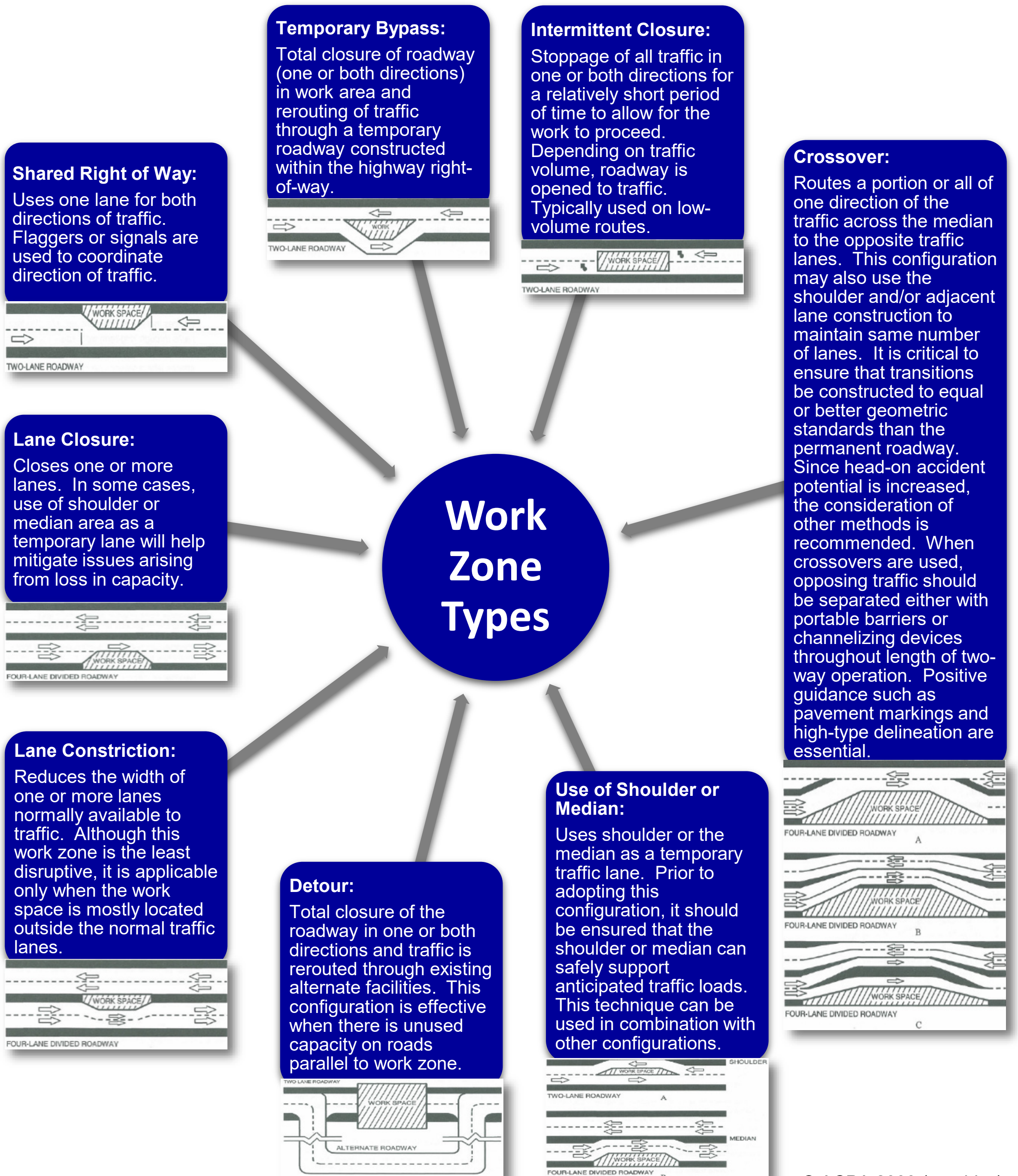

Figure 1. Work zone types (ACPA 2000).

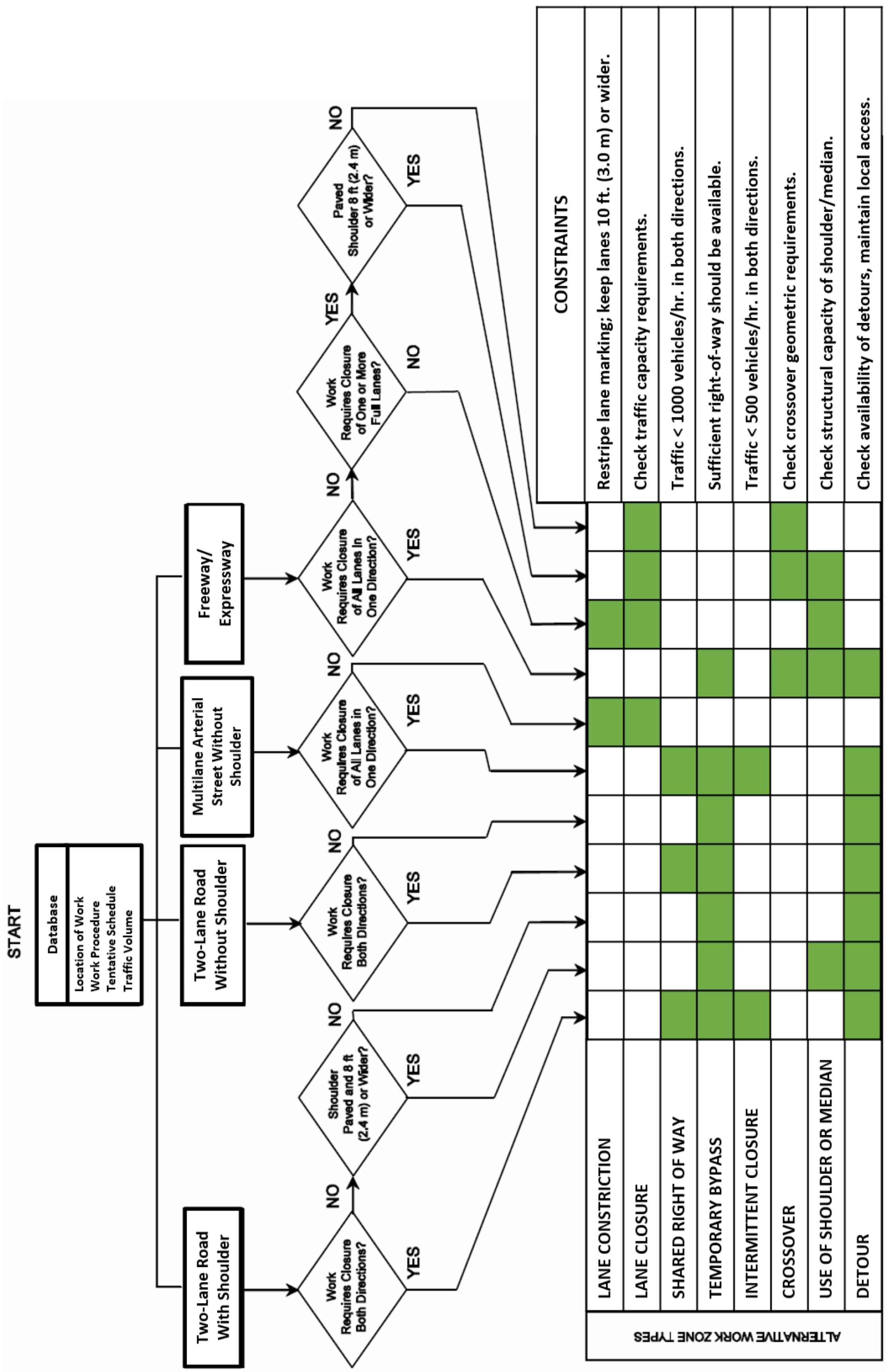

Figure 2. Identification of feasible work zone types (adapted from IDOT 2016).

Each agency should monitor the work zone crash experiences in their jurisdictions to determine the need for and application of the appropriate crash countermeasures to address site-specific safety issues.

ESTIMATING MONETARY EFFECTS OF WZTM

When the construction activities interfere with normal traffic operations, roadway users will incur costs due to delays, stops, and crashes. Several software tools are available to evaluate work zone impacts and support the identification of preferred practices, including the following (Van Dam et al. 2015):

- **CA4PRS** is a software tool supporting the analysis of project alternatives for different pavement design, construction logistics, and traffic operation options, and is designed to help highway agencies and contractors develop construction schedules to minimize traffic delay and reduce agency costs. Additional information on CA4PRS is available on the Caltrans Website.
- **QuickZone** is a software tool for traffic analysis that compares traffic impacts for work zone mitigation strategies and estimates traffic delays and cost. Additional information on QuickZone is available on the FHWA website.
- **Dynasmart-P** is a dynamic traffic assignment analysis tool used in decision making for regional work zone management. It models the evolution of traffic flows resulting from travel decisions of the individual travelers. It can be used to evaluate traffic management strategies for highway construction projects, and can also help assess the impacts of ITS technologies. Additional information is available on the FHWA website.

DEVELOPING A TRAFFIC MANAGEMENT STRATEGY

All work zone traffic control procedures including speed restrictions must follow the jurisdictional requirements specified in the latest version of the *Manual on Uniform Traffic Control Devices* (FHWA 2009). A number of possible alternatives to execute a project are expected to exist, and ultimately one alternative must be selected that optimizes the competing objectives of minimizing project costs, reducing construction downtime, and maximizing traffic safety and operational efficiency while taking the site-specific conditions into account. The five basic steps involved in developing a traffic management strategy for concrete pavement rehabilitation and reconstruction are summarized below (ACPA 2000). On a given project, the project-specific contract requirements should be reviewed and evaluated, as these may override some of these considerations.

Step 1: Identify Feasible Alternatives

The first step in the development of a traffic management strategy is the most critical, in that all feasible alternatives should be identified and depicted; some example traffic management strategies for concrete pavement rehabilitation projects are presented later in Appendix A.

When identifying feasible rehabilitation options for the existing pavement, several issues must be considered in addition to the condition of the existing pavement and the intended structural capacity of the new pavement; these include:

- **Phasing of work**: Can the project be completed in one construction season or will it require multiple phases? If winter shutdown is needed, which phases should be completed prior to the shutdown?
- **Work area length**: Is there a need to specify a maximum length of work area or lane closure?
- **Number of work areas**: While it is generally desirable to have one long work area rather than several short ones, the number of work areas should be limited when a long work area is not feasible.
- **Duration of Work**: How long is the work expected to last and what construction factors (such as curing time) will impact the duration of the project?
- **Temporary drainage**: Are drainage structures being altered, blocked, or added? Will normal drainage be affected during construction? What drainage provisions are needed during construction? What erosion controls are necessary?
- **Structural capacity of bridges, shoulders, and pavement**: If shoulders are used as traffic lanes during construction operations, are they structurally adequate to carry traffic during the work period? Are the bridges and pavements on detour routes functionally and structurally adequate?

- **Construction feasibility**: Does the required traffic control impact progress of work significantly? Does the work schedule interfere with local laws such as noise ordinances?
- **Existing traffic control devices**: Do any of the existing traffic control devices conflict with the adopted traffic management strategy? Do any of devices need to be covered, removed, or replaced? Is removal of pavement marking and installation of temporary pavement marking included in the traffic management plan?
- **Winter restrictions**: Will snow and ice removal be possible without interfering with the work zone setup? Is there adequate room provided to store the snow cleared off of the travel lanes? Will there be a requirement for items such as hot paint pavement marking instead of tape, barricades instead of drums, plowable pavement markets instead of raised markers, etc.?
- **Business and residential traffic service**: What are the necessary measures to maintain access? Should considerations be given to encroachments within grading limits that will create issues such as steep driveway entrances in and out of businesses? Is protected and clearly marked pedestrian access provided?
- **Lighting**: Is additional lighting needed for nighttime work? Should a lighting plan be prepared? Is any installed highway lighting expected to become permanent?
- **Special considerations**: Should any other special situations be addressed?

Some of the key considerations related to concrete pavement rehabilitation and reconstruction are summarized in table 1.

Step 2: Consider Planning Issues

In Step 2, various planning issues (related to such items as scoping, traffic management, construction requirements, safety, and so on) should be considered and evaluated; a checklist summarizing the planning considerations is provided in table 2. Additional details on each consideration listed in table 2 are provided in ACPA (2000).

Step 3: Compare Alternatives

In Step 3, the alternatives identified in Step 1 are compared and evaluated, based on addressing the critical needs of the project in order to determine the most suitable strategy to be adopted. As a part of this step, the allowable work hours and bidding alternatives are also taken into consideration.

Step 4: Choose Recommended Strategy

Step 4 then selects the recommended strategy based on comparison of the various alternatives considered in Step 3. Once the strategy to be adopted is finalized, a traffic control plan is developed and the key issues are highlighted and communicated to all parties that are involved or impacted by the project.

Step 5: Determine Phasing/ Key Constraints/ Special Provisions

Step 5 determines the project phasing, key constraints, and special provisions. This step involves considerations such as: (a) development of a contingency strategy for unusual conditions, (b) special construction provisions, such as paving in areas requiring narrow clearances, accelerated construction, nighttime work, and so on, and (c) development of a traffic detour plan in situations where longer than usual delays may occur. All the considerations identified in Step 5 are also documented in the traffic control plan developed under Step 4.

CONCRETE PAVING INNOVATIONS TO FACILITATE CONSTRUCTION

When designing work zones, both spatial requirements (work zone length and work zone lateral clearances) and the duration of the work activities must be considered. Several concrete paving innovations are available to address these time and spatial requirements and help facilitate the overall construction process, as described in the following sections.

Table 1. Concrete pavement rehabilitation and reconstruction considerations for traffic management (adapted from ACPA 2000).

Construction Activity	Key Considerations
Rehabilitation	• Length of work zone • Lighting for night work • Allowance for maneuvering large equipment (e.g., trucks, pavers, diamond grinding machines) • Concrete plant location • Allowing longitudinal joints to be at locations other than lane lines • Edge drop-offs • Entry and exit to ramps, side streets or businesses • Maintaining surface cleanliness (where needed for ultra-thin or bonded concrete to concrete overlays) • Curing time requirements and possible need for accelerated paving • Impacts of raising the shoulder grade • Temporary lane widening to accommodate public traffic around work area • Encroachment of adjacent lanes by slipform paver tracks or by workers performing other repair activities • Staging of construction activities (e.g., sawcutting repair boundaries or slot perimeters first and then removing material later) • Allowance for the use of precast elements to accelerate construction
Reconstruction	• Length of work zone • Lighting for night work • Allowance for maneuvering paving trains • Concrete plant location • Allowing longitudinal joints to be at locations other than lane lines • Edge drop-offs • Crown or cross-slope alterations • Curing time requirements and possible need for accelerated construction • Encroachment of adjacent lanes by slipform paver tracks • Entry and exit to ramps, side streets or businesses • Haul road configuration (use of subbase) • Structural capacity of bridges, shoulders, and potential detour pavements • Temporary drainage; utility work within right-of-way • Temporary lane widening to accommodate public traffic around work area • Allowance for a temporary accelerated construction schedule

Table 2. Planning considerations checklist (data source: ACPA 2000).

Areas of Consideration	Items/Issues to Consider
Traffic Management	• Capacity Analysis—lanes required, length of queues anticipated • Time restrictions—peak hours, seasonal peaks • Limits to work areas • Capacity of detour routes • Work vehicle access and worker parking • Bicycle and pedestrian traffic • Warning sign locations—detours, long queues, intersections • Railroad crossings/train schedules • Nighttime delineation/illumination • Signals, turning lanes, bus stops • Traffic service—residential/business • Future rehabilitation
Concrete Pavement Construction Requirements	• Accelerated construction—planning, concrete materials, construction requirements, curing, jointing • Opening to traffic—maturity, pulse velocity, strength requirements, cure time • Rehabilitation considerations • Off-peak traffic hours for increased production • Phasing of work—length of work zone, project limits • Special conditions such as drop offs, sign bridge installation, etc. • Pre-paving and paving restrictions • Special contract provisions needed • Short-duration closures anticipated • Temporary drainage • Lights for night work • Temporary roadway lighting
Safety	• Work zone crash rates • Traffic management strategies • Interstate system • Congestion • Nighttime • Large trucks • Workers on foot • Pedestrians • Local experience
Constructability	• Structural capacity of bridges, shoulders, and pavement • Timing of phases versus probable starting date • Strategy to allow contractor to finish project • Status of existing traffic control devices—signals, signs, railroad crossings, etc. • Wintertime restrictions—snow removal, etc.
Emergency Planning	• Incident management plans • Emergency medical assistance • Accidents, breakdowns, tow trucks • Severe storms and storm-water runoff • Emergency closures • Utility interruptions • State police • Local law enforcement
Public Information Coordination	• Public information—public hearings, media, motorist service agencies, residents, local businesses, motor carriers • Local officials—police, fire, hospitals, schools, environmental agencies, utilities, toll facilities, ferries, railroads, airports • Special events • Intra-agency coordination—maintenance crews, permits section, adjacent project • Transit

Reducing Clearances

When configuring work zones, adequate clearances must be provided to accommodate the paving equipment's tracks and frame as well as the stringline setup. For a typical concrete paver, the clearance required on either side of the paving machine is 4 ft (1.2 m); that is, 3 ft (0.9 m) for the paver track and 1 ft (0.3 m) for the stringline. These clearances do not include the space requirements for traffic control devices, workers, and roadway users (Harrington and Fick 2014). Figure 3 shows a concrete pavement construction operation with a conventional stringline paver.

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Figure 3. Conventional stringline paver.

In certain situations—such as narrow roadways, minimum or absence of shoulders, traffic in adjacent lanes, and presence of safety barriers or retaining walls—reduction of paving equipment clearances may be required. Zero-clearance paving can be achieved to accommodate site-specific conditions through proper planning and coordination. Paving machine manufacturers have developed specialized equipment to execute projects where clearance issues may exist. Additionally, several contractors around the country have modified the standard paving machines to enable zero-clearance paving. It should be noted that the clearance in zero-clearance paving must still include the 6 to 8 inches (150 to 200 mm) for the paving machine edge form.

In addition to the use of zero-clearance pavers, there are other methods of reducing the lateral encroachment of the work zone. For example, instead of a stringline a contractor may make use of mechanical paving control options such as an average profiler, a movable stringline, or a ski, provided that smoothness requirements are achieved. Additionally, stringless paving may be used in which the need for traditional stringlines is eliminated and replaced with electronic tracking process that controls the horizontal and vertical operation of the paver through the use of global positioning system (GPS), robotic total stations, and laser positioning (Harrington and Fick 2014). Figure 4 shows a stringless paving operation.

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Figure 4. Stringless paving operation.

Additional Clearance Requirements

Beyond the clearances required for the paving equipment, there is the need to provide clearances to accommodate other activities within the work zone. For example, adequate clearance must be allowed for traffic control devices (cones, signs, barriers, temporary signals) as well as for the accommodation of construction workers and their tools as they perform their activities (e.g., floating/finishing concrete, which is recommended to be done on the non-trafficked side of the roadway) (Harrington and Fick 2014). The width of this clearance zone depends on a variety of factors such as traffic volume, traffic speed, and agency-specific requirements.

Accelerated Construction

In certain situations, construction operations need to be expedited and the roadway is required to be opened to traffic very quickly. This is achieved by employing accelerated construction techniques. Modifications and adjustments to conventional concrete paving materials and procedures can significantly accelerate construction, but that is only one component in accelerating the overall construction process. The key considerations include adjustments to concrete mixture proportioning, changes in worker responsibilities, construction staging, joint construction, and opening-to-traffic criteria (as summarized in table 3).

Table 3. Best practices for concrete pavement construction and key considerations for reducing construction time (data source: ACPA 2000; Van Dam et al. 2005; Taylor et al. 2007).

Project Component	Considerations for Accelerated Construction
Planning	• Allow nighttime construction • Allow contractor to use innovative materials, equipment, or procedures • Allow innovative construction staging to minimize closures and increase construction efficiencies • Use time-of-completion incentives and disincentives • Modify requirements for paver width at structure or other confined locations
Cement and Concrete Materials	• Develop a quality control plan and follow best practices for stockpile management, batching, mixing, delivery, and testing of concrete • Inspect concrete plant prior to start of each paving project • Minimize variability of concrete production process to ensure consistent quality • Account for variations in materials through proper planning and adjustments in the field • Use suitable chemical and mineral admixtures • Use an optimized aggregate gradation • Reduce water-to-cementitious materials (w/cm) ratio while increasing aggregate volume and maintaining appropriate workability • Use high-early strength mixtures only in applications where the decrease in user costs can justify added expense and risk • Verify adequacy of air-void system for concrete mixtures, especially for high-early-strength mixtures. • Conduct testing on job mixture during mix design and construction monitoring • Follow best construction practices to ensure durability
Jointing/Sealing	• Allow early entry sawcutting equipment • Use narrow, single-cut joints • Consider joint filling instead of joint sealing
Curing, Temperature, Strength Testing, Thickness Verification, and Smoothness	• Specify blanket curing to aid strength gain, as allowed and when appropriate • Make preparations for hot- or cold-weather paving or rain events well in advance • Conduct testing on fresh and hardened concrete • Use concrete maturity or pulse-velocity to monitor strength development and determine opening times • When appropriate, use non-destructive testing for verifying layer thicknesses • Use real-time smoothness measurements
Traffic Opening Criteria	• Revise from time to strength criteria (flexural, compressive) • Channel early loads away from slab edges • Restrict use to automobile traffic during early ages

While accelerated construction techniques have the capability to significantly reduce construction downtime, it should be noted that in some cases the long-term durability of the pavement may be negatively impacted due to the adoption of unconventional materials and procedures (Van Dam et al. 2005). Accelerated construction should only be used in situations where it is absolutely warranted, and adequate considerations should be given to the quality of the final product. Additional guidance on accelerated construction is available elsewhere (ACPA 1994; Van Dam et al. 2005; Taylor et al. 2007; Crovetti and Khazanovich 2005).

SUMMARY

This Tech Brief summarizes the key aspects of work zone traffic management, which involves more than just providing traffic control in a work zone. It includes a wide range of activities that involve strategies for moving people and goods safely and efficiently through a traffic corridor (ACPA 2000). Considerations and general guidelines for developing and implementing a traffic management strategy are described. Concrete pavement construction-related innovations that help streamline work zones and improve the overall efficiency of the construction process are discussed. Example traffic control and management strategies for concrete pavements are presented in Appendix A.

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APPENDIX A: EXAMPLES OF TRAFFIC CONTROL AND MANAGEMENT STRATEGIES FOR CONCRETE PAVEMENTS

This appendix provides examples of traffic control strategies for some common types of concrete pavement rehabilitation and reconstruction activities. Strategies for two-lane highways, multi-lane divided highways, and urban areas are discussed. Additional details are available in the engineering bulletin on *Traffic Management* (ACPA 2000) and the *Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements* (Harrington and Fick 2014), as well as in the *Manual on Uniform Traffic Control Devices* (FHWA 2009).

Two-Lane Highways

Table A.1 presents various traffic control strategies for rehabilitation and reconstruction activities performed on a two-lane highway. An example illustrating the construction sequencing/staging for the placement of a concrete overlay on a two-lane roadway is shown in figure A.1, while figure A.2 presents an illustration of the typical construction phasing for reconstruction of a two-lane highway.

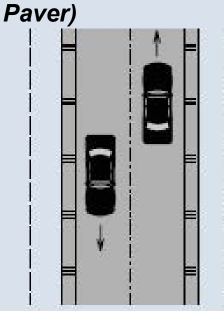
Table A.1. Traffic control strategies for rehabilitation activities on two-lane highways (data source: ACPA 2000).

Strategy	Details
Close One Side of a Two-Lane Highway	• One side of highway is closed to traffic during work hours and highway is returned to two-way operations during non-working hours. Appropriate warrants specified in the MUTCD should be used. • Requires alternating traffic flow and a shared right-of-way on the open side which can be accomplished through three basic methods: – Flagger Operations: Used for short-term, short-length work zones. Can be closed with flaggers, desirably in sight of each other who can alternate flow of traffic. – Pilot Car Operations: Used for short-term, long-length work zones where work requires a curing time before highway can be reopened to traffic. Pilot cars proceed traffic and reduce potential danger of approaching vehicle. – Traffic Signal Operations: Used for long-term, short-length operations for work activities typically involving removal of a section of roadway of a short length when work areas remain closed to traffic during nights and weekends. Temporary signal installations must be over relatively short sections where drivers can see opposing stop area. On roads with low traffic volumes, work zones may be controlled with stop or yield signs or be self-regulating.
Use Shoulders as Traffic Lanes	• Patching, repair or other restoration work can be performed by channelizing traffic onto shoulders and providing for a suitable work area. • Traffic control layouts should be developed on the basis of amount of roadway width available at the most constricted point. • Though structural analysis is typically not required, traffic control plans should be checked against pavement and shoulder strength. Shoulder must have enough strength to support all vehicles during work or must be strengthened as the first phase of the project.
Use Multiple Work Areas	• Multiple work areas are used when work areas are located in several isolated spots. • This strategy is generally not preferred since it requires multiple sets of traffic control devices and can be confusing to the road user.
Advancing or Decreasing Lane Closures	• Lane closure length is adjusted during the day in order to minimize driver delay in one lane alternating traffic situations. Some key considerations are discussed below. – Decreasing Work Area: This strategy establishes the maximum feasible work area for the morning traffic condition and decreases the size of the work area as the work progresses and the pavement is cured. This approach is suitable when the traffic volume is low in the morning and increases through the day. – Increasing Work Area: The work area is initially limited during the morning hours and as traffic decreases during mid-day hours, the work area is extended. The work area can be reduced again during the rush hours in the evenings. – Specifying when work or particular types of work can or cannot be performed: Includes requirements to open traffic lanes by a certain time, allowing certain work types only on weekends, requirements to performance certain work operations only during nighttime etc. – Incentive and Disincentives: Involves paying the contractor a fixed rate for every hour that the contractor opens the roadway ahead of schedule and fining the contractor a fixed amount for every hour that the highway remains closed after a specified time.
Leapfrogging Traffic Control	• Requires contractor to include sufficient work zone traffic control devices to construct full area and sufficient additional devices to establish next work zone closure downstream from initial taper, but still within initial lane closure. • Allows contractors to establish new tapers and sign layouts in the relative safety of existing work area and reduces time that traffic control devices are off the roadway.
Close Road and Detour Traffic	• Feasibility of road closures and detours is determined based on the availability of, and convenience of access to, alternate routes and their ability to support the increase in traffic (both structurally and in terms of capacity).

COMPLETED OVERLAY (Two-Lane Roadway with Paved Shoulders, Conventional Paver)

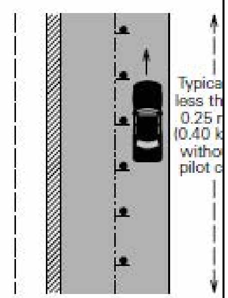
Applied to:

- ☑ Bonded concrete overlay of concrete pavements
- ☑ Bonded concrete overlay of asphalt pavements
- ☑ Bonded concrete overlay of composite pavements
- ☑ Unbonded concrete overlay of concrete pavements
- ☑ Unbonded concrete overlay of asphalt pavements
- ☑ Unbonded concrete overlay of composite pavements



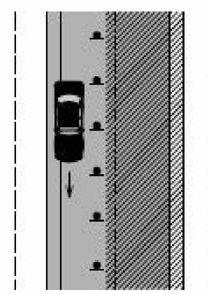
STAGE 1. Repair surface, prepare for overlay, and construct base shoulder widening and separation layer

- Install traffic control and close the left lane. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lane may require additional traffic control (e.g., signals, flaggers, and/or pilot cars).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Prepare for shoulder widening by trenching the existing shoulder and trimming to the specified width. The trench should be rolled and compacted as necessary to obtain a firm and stable platform as specified in the contract documents. A continuous progression approach with the shoulder trencher and placement of the base shoulder widening material is encouraged.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. Construct right shoulder and concrete overlay

- Shift the traffic control to the left lane and close the right lane to traffic. The length of the closure will depend on the jurisdiction's maximum closure length with pilot car. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay).
- Normal space for the paver stringline is 1–1.50 ft (0.30–0.46 m) and the paver track is a minimum of 2.50–3 ft (0.76–0.91 m). 1 ft (0.3 m) incremental encroachment reduction (up to 2 ft (0.6 m) total) is common through typical machine adjustment. Speeds should be additionally restricted adjacent to paver when clearance between the paver and vehicle traffic is tight.
- Construct concrete overlay on the existing pavement. Complete right PCC shoulder widening with the overlay. Bull float work shall operate from the outside shoulder only.
- The "X" dimension between the roadway centerline and vertical panel is for the paving machine track and stringline.



STAGE 3. Construct left lane concrete overlay

- Close the opposite lane to traffic and place the concrete overlay according to contract documents, using the same procedures as described in stage 2. Note that stringline may not be necessary for the right edge of the paving when the paved overlay constructed in stage 2 is used as the paver control in this stage. If the right stringline is not used, the "X" dimension could possibly be reduced to 3 ft (0.9 m).
- If the outside edge dropoffs at the shoulder exceeds the jurisdictional allowance for a 1:1 fillet, then construct the granular shoulders in this stage.
- Complete shouldering. Install (mill) rumble strips in the paved shoulders and complete pavement marking and regulatory signing in accordance with contract documents.

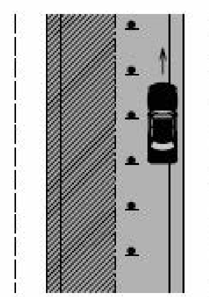


Figure A.1. Concrete overlay of two-lane roadway with paved shoulders (Harrington and Fick 2014).

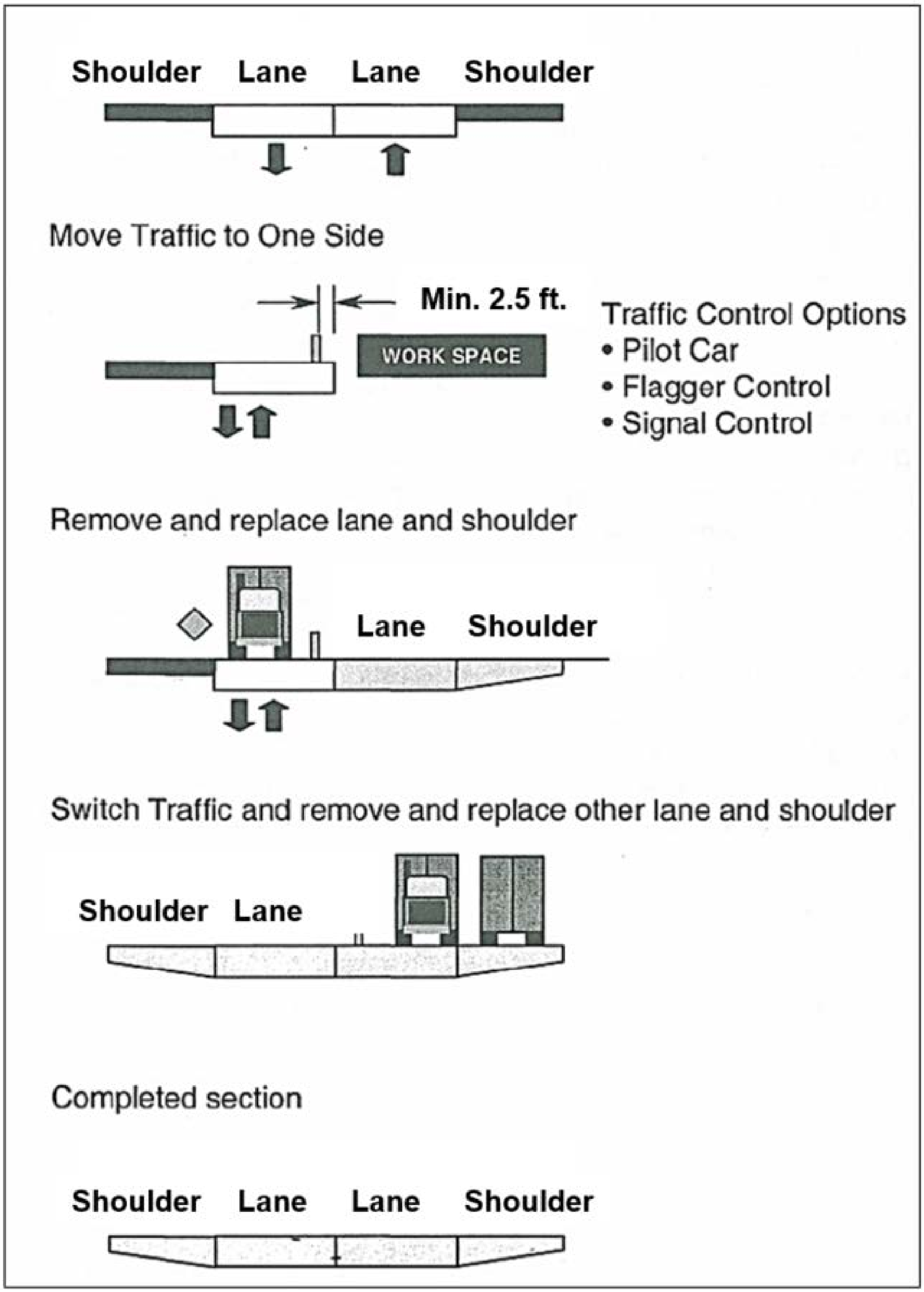


Figure A.2. Concrete reconstruction of a two-lane two-way highway (ACPA 2000).

Multi-Lane Divided Highways

Table A.2 presents traffic control strategies for rehabilitation and reconstruction activities performed on multi-lane divided highways. An example illustrating the construction sequencing/staging for the concrete overlay of a four-lane roadway is shown in figure A.3, while figure A.4 presents an illustration of the typical construction phasing for reconstruction of a six-lane highway.

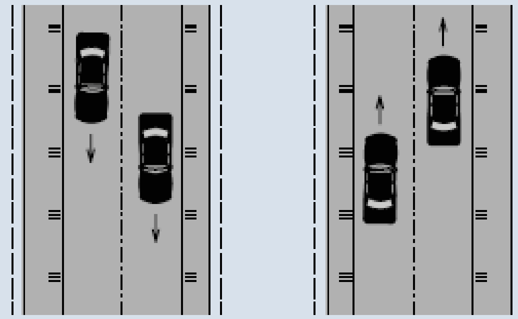
Table A.2. Traffic control strategies for rehabilitation activities on multi-lane divided highways (data source: ACPA 2000).

Strategy	Details
Close One Lane for Entire Length	• This is the simplest form of lane closure which gives the contractor more flexibility for the work operations. However, this strategy may penalize road users by making the work zone longer than necessary.
Alternating Lane Closures	• In this strategy, one lane is closed for a specific length and after that the adjacent lane is closed while the first lane is re-opened. • Reversible lanes can be used, which is a type of alternating lane closure when the direction of traffic is reversed based on peak directional volumes. The reversible lanes should be kept clear when not being used. • Movable Concrete Barrier (MCB) is an innovative method to accomplish the alternating lane closure strategy to provide reversible or other extra lanes during peak traffic periods.
Multiple Work Areas	• Multiple work areas are used when work areas are located in several isolated spots. • This strategy is generally not preferred since it requires multiple sets of traffic control devices and can be confusing to the road user.
Advancing Limited Closure in One Lane	• A lane closure is instituted and then lengthened or shortened based on traffic and type of construction activity. Typical example is a paving operation when a short length of lane is closed and then expanded as the paving operation progresses.
Leapfrogging Limited Closure	• Allows workers to setup a lane closure taper within an existing lane closure and the lane closure can then be shortened as the work progresses.
Lane Shifts onto Shoulder or Median	• This strategy is usually considered where lane closures would result in unacceptable delays. • The number of active lanes are kept the same by channelizing traffic onto shoulders or medians. • Traffic control layouts should be developed on the basis of amount of roadway width available at the most constricted point. • Though structural analysis is typically not required, traffic control plans should be checked against pavement and shoulder strength. Shoulder must have enough strength to support all vehicles during work or must be strengthened as the first phase of the project.
Close Road and Detour Traffic	• Feasibility of road closures and detours is determined in the same manner as for two-lane highways. Since multi-lane highways normally have higher traffic volumes, the use of this strategy is very limited.
Close One Side and Operate Two-Lane Two-Way Traffic on Opposite Side	• In this strategy, median crossovers are constructed to divert direction of traffic to the roadway normally used by the opposite direction. Traffic then operates like a two-lane two-way highway. This strategy is discussed in Part VI of the MUTCD.

COMPLETED OVERLAY (Four-Lane Roadway with Paved Shoulders, Conventional Paver)

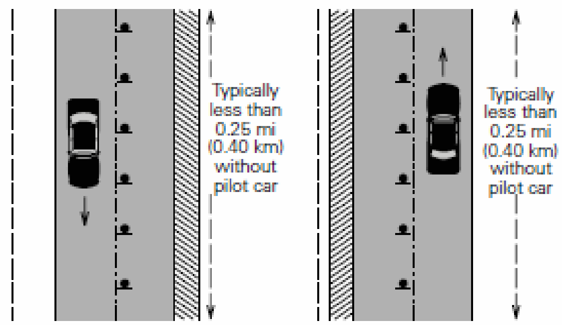
Applied to:

- ☑ **Bonded concrete overlay of concrete pavements**
- ☑ **Unbonded concrete overlay of concrete pavements**
- ☑ **Bonded concrete overlay of asphalt pavements**
- ☑ **Unbonded concrete overlay of asphalt pavements**
- ☑ **Bonded concrete overlay of composite pavements**
- ☑ **Unbonded concrete overlay of composite pavements**



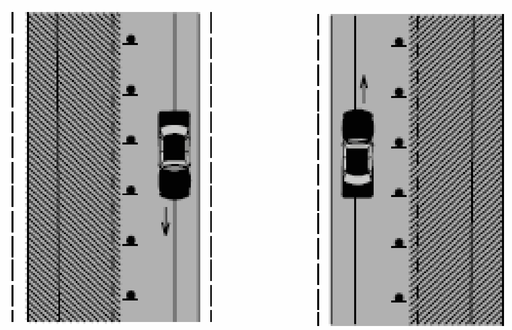
STAGE 1. *Repair surface and prepare for overlay*

- Install traffic control and close the inside lanes. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lanes may require additional traffic control (e.g., signals and flaggers).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Evaluate the structural condition of the existing shoulder. Mill existing shoulder or reconstruct shoulder to carry traffic load if necessary.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. *Construct concrete overlay on outside lane*

- Shift the traffic control to the inside lanes and close the outside lanes to traffic. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay).
- Construct temporary shoulder for paver track.
- Construct concrete overlay on the existing pavement. Bull float work shall operate from the outside shoulder only.



STAGE 3. *Construct concrete overlay on inside lane*

- Shift the traffic control to the outside lane and close the inside lane to traffic. Place the concrete overlay according to contract documents, using the same procedures as described in stage 2. Stringline may not be necessary for the right edge of the paving when the paved overlay constructed in stage 2 is used as the paver control in this stage.

If the right stringline is not used, the "X" dimension could possibly be reduced to 3 ft (0.9 m).

- Complete shoulder finish grading. Install (mill) rumble strips in the paved shoulders and complete pavement marking and regulatory signing in accordance with contract documents.

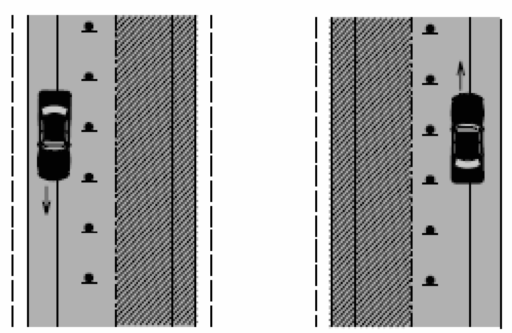


Figure A.3. Concrete overlay of four-lane divided roadway with paved shoulders (Harrington and Fick 2014).

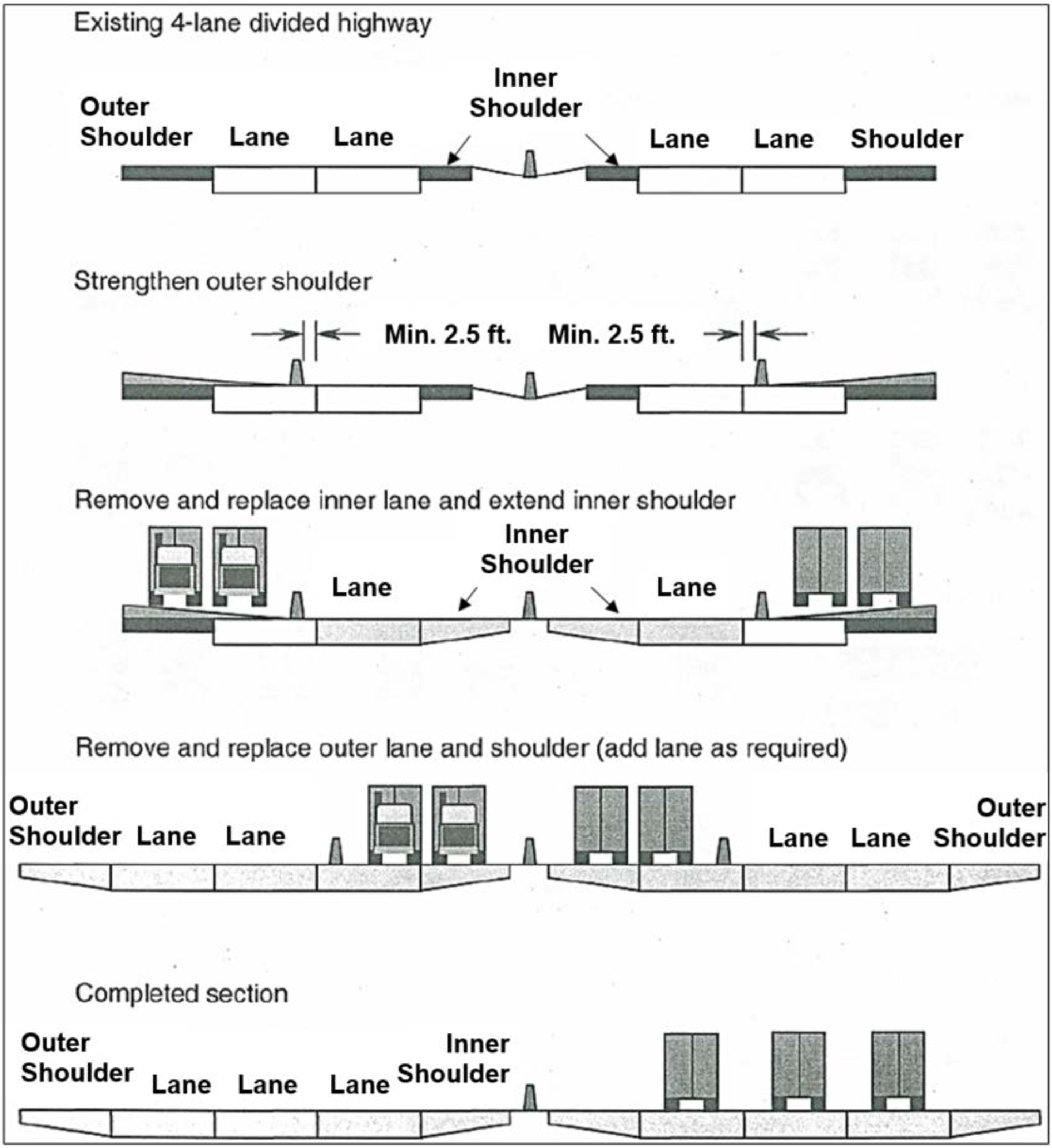


Figure A.4. Concrete reconstruction of a four-lane divided highway to a six-lane divided highway with concrete shoulders (ACPA 2000).

Urban Areas

Urban street systems present unique challenges in developing and maintaining traffic control. Projects in urban areas must not only consider vehicle traffic volume but a host of other factors such as turning movements at intersections, pedestrian traffic, access to businesses, parking, bus routes and stops, school zones, emergency services, and other traffic-related operations common to urban areas. Potential strategies for work in urban areas include (ACPA 2000):

- Modifying traffic patterns by restricting turning movements, changing signal times, using temporary one-way street couples, or other traffic control methods to reduce or eliminate traffic from selected work areas.
- Closing one or more blocks of a street to traffic, generally for limited periods of time and modifying the surrounding traffic patterns.
- Eliminating either shoulders and/or parking to provide for existing traffic while having adequate room for a work area.
- Closing a highway section or street at night and restoring traffic operations, possibly on a temporary milled surface during peak traffic periods.

Part VI of the MUTCD discusses many of these strategies. Work zones in urban areas should normally permit access to homes and businesses and hence is usually performed as short-term work even in a long-term project. In some situations, accelerated construction technologies (discussed earlier) may be employed to minimize facility downtime. The primary factors involved in developing a traffic control plan for urban streets include the following (ACPA 2000):

- Traffic volumes and traffic distribution.
- Traffic mix, including trucks and transit busses and areas they serve.
- Location of access to businesses, type of business and traffic generation, private and public parking areas.
- Traffic signal timing, traffic counts including turning movements, pedestrian counts, and any restrictions.
- Roadway width, traffic regulations in effect (signs and markings), other signing, parking restrictions, fire hydrants.
- Proximity of residential areas and noise restrictions.
- Coordination with adjacent local construction or utility projects.

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