Work Zone Positive Protection Toolbox

This booklet serves as a toolbox to describe various types of positive protection devices currently in use and provides guidance on where and how each is typically used.

ATSSA
SAFER ROADS SAVE LIVES

U.S. Department of Transportation
Federal Highway Administration

Developed by:
The American Traffic Safety Services Association (ATSSA)
15 Riverside Parkway, Suite 100
Fredericksburg, VA 22406-1022
800-272-8772

This material is based upon work supported by the Federal Highway Administration under grant agreement No. DTFH61-06-G-00004

Index

Work Zone Positive Protection Toolbox

This document is part of series of products developed under the Federal Highway Administration (FHWA)-sponsored American Traffic Safety Services Association (ATSSA) Work Zone Safety Grant DTFH61-06-C-00004. It serves as a toolbox to describe various types of positive protection devices currently in use and provides guidance on where and how each is typically used. A Federal Highway Administration brochure (1) defines positive protection as "***a device which contains and redirects vehicles in accordance with National Cooperative Highway Research Program (NCHRP) Report 350, preventing their intrusion into the workspace.***" These devices may also be used to protect the road user from entering other hazardous areas in a highway work zone, such as deep pavement edge drop-offs, and to shield pedestrians and workers.

Several types of positive protection devices are currently available to enhance worker and motorist safety in construction areas. They include portable concrete barriers, ballast-filled barriers, and moveable concrete barriers, as well as shadow vehicles with truck-mounted attenuators, and vehicle arresting systems that prevent road users from entering a closed section of roadway. Each has unique characteristics and there are different construction site situations that can benefit from the use of one or more devices.

Recent updates to the Work Zone Safety and Mobility Rule (2) require agencies to establish policies, procedures, and/or guidance for the systematic consideration and management of road user and worker safety on Federal-aid highway projects. Specifically, the Rule states that such items "***shall address the use of Positive Protection Devices to prevent the intrusion of motorized traffic into the work space and other potentially hazardous areas in the work zone.***" Additionally, the Rule requires consideration of standards and/or guidance contained in the *Manual on Uniform Traffic Control Devices (MUTCD) (3)*, the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide (RDG) (4)*, and project characteristics. NCHRP Synthesis 20-7 (174): *Positive Protection Practices in Highway Work Zones (5)* provides a summary of current positive protection practices in the United States.

Determining the Need for Positive Protection

The Rule requires consideration of positive protection, but allows flexibility for agencies to determine how and when to use it. This determination should be based on a project specific engineering study or agency guidelines. The *RDG* offers guidance on the use of barriers, but the actual decision on whether positive protection is needed, and the best type of device to use for a specific work zone situation, is typically determined by an engineering study that considers the actual conditions expected to be encountered in the work zone combined with the characteristics of the various devices that may be available.

Characteristics that should be considered in combination to help with the decision include project scope and duration, anticipated traffic speeds through the work zone, anticipated traffic volume, vehicle mix, type of work, distance between traffic and workers, escape paths, time of day, work area restrictions, roadway departure issues for users, access to and from the work space, type of roadway, impacts on project cost and duration, and other hazards.

Selecting an Appropriate Temporary or Portable Barrier System

Several types of positive protection systems are available that meet the test levels (TL) in ***NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features (6),*** and a number of different designs are available for each. Proper temporary barrier system selection and design involves the consideration of a number of specific factors including:

- The NCHRP Report 350 test level needed to accommodate expected impact conditions (devices are classified into categories in the report based on characteristics such as the weight of the device).
- Duration and ease of installation, maintenance, and removal.
- Exposure and safety risks for workers and road users during installation, repair and removal.
- Expected frequency and severity of impacts (based in part on crash data).
- Available space for barrier installation and lateral deflection (perpendicular to traffic flow).

This toolbox highlights five positive protection devices – **Portable Concrete Barriers, Movable Concrete Barriers, Ballast-Filled Barriers, Shadow Vehicles, and Vehicle Arrestor Systems** - and lists characteristics of each along with guidance for their use. Illustrations of each device are provided.

Channelization

While the primary function of a longitudinal barrier is protection, it may also serve to channelize traffic, especially when markings and other devices are added to the barrier to enhance its visibility. Additionally, channelization may be enhanced for nighttime lane closures using warning lights or retroreflective elements attached to the barriers. Conspicuous markings are also important on shadow vehicles and arresting systems to make them visible to motorists.

The Roadside Design Guide (RDG) also points out that there are a number of longitudinal channelizing systems, typically constructed from plastics or similar materials, available for use in work zones. The function of channelizing devices is "***to warn road users of conditions created by work activities in or near the roadway and to guide road users.***" Section 6F.66 of the Manual on Uniform Traffic Control Devices (MUTCD) describes these longitudinal channelizing systems and points out that they "***should not be used to protect pedestrians – including workers – from vehicle impacts or obstacles***" because they have not met the crashworthy requirements for traffic barriers. In simple terms, they delineate the traveled way but are not designed to prevent a vehicle from intruding into the work space or other hazardous area. Additionally, many channelizing devices will not protect road users from hazards. Some water filled channelizing devices are easily confused with Ballast-filled Barriers (see below.)

End Treatments

Both the RDG (Section 9.1) and the MUTCD require proper end treatments on temporary barriers to reduce the severity of impacts on the barrier end. Acceptable end treatments include:

- Appropriate connection to an existing crashworthy barrier to avoid exposure to the barrier end.

- Attachment to a crashworthy end treatment such as an impact attenuator.

- Flaring the end of the barrier beyond the edge of the clear zone (an area off the edge of the travel way that should be free of hazards).

- Burying the end in the backslope so that vehicles avoid direct impact with the end.

Portable Concrete Barrier

What is a Portable Concrete Barrier?

A portable concrete barrier – PCB – is defined in the RDG as a set of "freestanding, precast, concrete segments, 8 feet to 30 feet in length, with built-in connecting devices." Their profiles follow the same contours as other safety shaped concrete barriers used for permanent installations.

A recent survey of practices confirmed that PCB is the option most frequently used by state transportation agencies. The RDG highlights a total of eight PCB systems, all of which have been crash-tested and meet NCHRP Report 350 criteria. The FHWA roadside safety website (*http://safety.fhwa.dot.gov/roadway_dept/road_hardware/index.htm*) includes at least 24 acceptance letters for portable concrete barriers that can be used on highway projects. Thus, a variety of specific designs for PCB meeting the NCHRP 350 criteria and accepted by FHWA are available for use. Additional details on PCB are provided in the recent report *Performance Evaluation of the Portable Concrete Barriers (7)*.

How is it Used?

Figure 1. Portable Concrete Barrier Separating the Traffic Space and Work Space

PCB is placed between the traffic space and work space to prevent vehicle intrusions, and may also be placed between opposing traffic lanes, and between travel lanes and roadside hazards. Because PCB consists of individual segments connected by flexible joints, PCB is subject to lateral deflection (movement of the barrier parallel to traffic) when impacted. The amount of impact deflection is dependent upon section length, the joint connection system used, and other factors. To control or eliminate lateral deflection close to pavement edge drop-offs and in other situations where deflection space is limited, barrier sections may be anchored to the pavement. On bridge decks, overpasses, and any other edge drop off, such as retaining wall copings where no deflection can be accommodated, anchoring of the barrier by bolting down the front face is required. Placing an anchor behind a PCB will simply cause it to overturn on impact.

Work Zone Design Considerations for Portable Concrete Barrier Use

The *RDG* discusses a number of design considerations that need to be addressed in the application of PCB. These include the following:

- Flare rate – the rate at which PCB approaches the traveled way – recommended flare rates are provided in the *RDG* in Section 9.2.1.1.1.

- Minimum offset – a minimum offset of 2 feet from the edge line of the travel lane to the PCB is considered desirable. Low lateral clearances may adversely impact traffic flow.

- Joint connections – because PCB consists of individual segments, adequate joint strength and continuity is essential to ensuring good impact performance. The *RDG* and FHWA website describe several acceptable options for joint connections that permit PCB to deflect from less than one foot to more than seven feet.

- Base coarse friction and barrier-to-base connection – parameters that control the amount of sliding that occurs on impact, thus affecting lateral impact deflection (see *RDG*).

- Performance level – Many PCB designs have been tested at NCHRP 350 test level three (TL3) and are acceptable for use on higher speed roadways. However, some designs are approved at NCHRP 350 test level two (TL2) and may be used only when approved by the highway agency.

Figure 2. Moveable Concrete Barrier and Transport Machine

Moveable Concrete Barrier

What is a Moveable Concrete Barrier (MCB)?

As described in the RDG, the MCB system consists of approximately 3-foot long segments of barrier connected by steel pins to form a barrier wall that is moved laterally with a transport/transfer vehicle.

How is it Used?

For certain long term work zones requiring frequent changes to the traffic pattern, an MCB system may offer a practical method of providing both positive barrier protection and frequent opening and closing of traffic lanes. MCB systems are also used to reverse lanes during construction to provide additional peak hour directional capacity.

The time and effort required for initial installation and placement of MCB is similar to PCB. However, once installed, the MCB can be moved laterally more easily and quickly than PCB. A one-mile section of MCB can be transferred laterally the width of a travel lane in about 15 minutes. A major advantage of this system is that the lateral transfer takes place without the need for additional traffic protection, because the transfer vehicle is fully protected from traffic in each direction by the MCB itself.

Work Zone Design Considerations for Moveable Concrete Barrier Use

Lateral impact deflections of the MCB are in the same range as many unrestrained PCB systems. This system is described in Section 6F.81 of the MUTCD, and its application is illustrated in Figures 6H-34 (Typical Application 34) and 6H-45 (Typical Application 45). Since the barrier is moved on a daily basis, no pavement edge lines are used. Reflectors should be used on the MCB to delineate the barrier and lane edge.

The *RDG* reports that several variations of this proprietary system have been tested and shown to meet NCHRP 350 test level three criteria. Potential benefits of using this system include increased traffic capacity while maintaining positive barrier protection for motorists and workers.

Ballast-Filled Barrier

What is a Ballast-Filled Barrier?

The RDG (9.2.1.3) describes this type of barrier as "***longitudinal barriers of segmented, polyethylene plastic shells (with a steel framework for NCHRP TL3), designed for use with a ballast, that have been successfully crash tested to NCHRP 350 requirements***." Ballast may be water or sand.

Figure 3. Empty Ballast-Filled Barrier Segments

How is it Used?

A ballast-filled barrier is used in essentially the same way as other temporary longitudinal barriers – PCB and MCB. An advantage of this type of barrier is ease of placement due to lower weight during installation. Empty barrier sections can be placed by hand without the need for heavy lifting equipment, thus permitting its use where the use of heavy equipment may be impractical or impossible. Once the plastic sections are installed the steel rail or rails are added to redirect impacting vehicles. Water is then typically used as ballast to help anchor the barrier.

Work Zone Design Considerations for Ballast-Filled Barrier Use

Even when filled with ballast, lateral impact deflections are generally greater for ballast-filled barriers than for PCBs. A cubic foot of water weighs about half of an equal volume of concrete. Ballast-filled barriers can be used safely only where the expected lateral deflection can be accommodated without conflicting with workers or other potential hazards behind the barrier. Ballast-filled barriers are designed for use in low speed urban areas and to contain vehicles with a weight of 4000 pounds or less. These barriers may have large deflection (6 to 25 feet) when impacted. Vehicles can be expected to penetrate completely through ballast-filled barriers that omit the internal or external steel rails.

The *RDG* (9.2.1.3) describes two ballast-filled barriers that have been successfully crash tested and are available for use as temporary traffic barriers. Depending on the configuration used, these barriers meet NCHRP 350 test level two and test level three standards (5). The FHWA roadside safety website includes 16 acceptance letters for various ballast-filled barriers through January 25, 2005. These devices include a range of designs approved for three NCHRP 350 test levels.

Another important consideration for this system is the effect of the water ballast when impacted. It may create a hazardous situation in the work zone, especially in cold temperatures if it forms ice on the pavement. Further, the means to dispose of the ballast water when the barrier is removed should also be considered. While it may be possible to drain the water onto the ground in many locations, some locations may require that the water is pumped out and transported off-site, thus adding to the time and cost to remove the barrier. Additionally, sodium chloride or environmentally friendly antifreeze can be used to keep the water from freezing while inside the barrier. Consequently, environmental guidelines and restrictions should be adhered to when draining barriers.

Shadow Vehicles

What are Shadow Vehicles (SV)?

The *MUTCD* describes an SV as a truck or trailer used to protect workers or work equipment from errant vehicles. SVs are normally equipped with flashing arrows, and/or changeable message

Figure 4. Shadow Vehicle with Attenuator

signs, and/or high-intensity rotating, flashing, oscillating, or strobe lights, and are located in advance of the workers and/or equipment that they are protecting. However, SVs might themselves cause injuries to occupants of the errant vehicles if they are not equipped with truck-mounted attenuators. Truck-Mounted Attenuators (TMAs) or Trailer-Mounted Attenuators are energy-absorbing devices attached to the rear of an SV that are designed to lessen impact severity for occupants of the impacting vehicle, and to some extent, occupants of the SV.

How are Shadow Vehicles Used?

The *MUTCD* (6D.03) states that "***in the case of mobile and constantly moving operations, such as pothole patching and striping operations, a shadow vehicle, equipped with appropriate lights and warning signs, may be used to protect the workers from impacts by errant vehicles. The shadow vehicle may be equipped with a rear-mounted impact attenuator.***"

Typical applications for SVs include moving or mobile operations, maintenance operations, paint striping, and other short duration operations. They may also be positioned upstream of workers in stationary work zones where it is not practical to use PCB or other temporary longitudinal barriers. Several Typical Applications in the *MUTCD* provide guidance on placement of SVs. When used in stationary applications, SVs should be positioned in the work space and not in the buffer space.

Work Zone Design Considerations for Shadow Vehicle Use

Highway, traffic, and work zone characteristics must be considered in determining the need for SVs and TMAs. The *RDG* (see Table 9.3 for application guidelines) discusses priorities for the use of SVs and TMAs, as well as their recommended positioning in the work zone. Additional state-level specifications may be available for use of shadow vehicles in addition to some typical applications listed in the MUTCD.

SVs may be displaced forward by the force of an impacting vehicle – termed roll-ahead distance. Adequate roll ahead distance should be provided between the SV and the workers or equipment it protects. In addition to the positioning guidance in the *RDG* (*Section* 9.3.2.2), it is important to follow transportation agency specifications and guidelines for use of SVs (as is the case for all the products mentioned in this toolbox), as well as manufacturers' recommendations when the SV is equipped with a TMA. Table 9.4 in the *RDG* also lists guidelines for spacing of SVs.

Figure 5. Vehicle Arresting System Protecting Closed Highway Section

Vehicle Arresting Systems

What are Vehicle Arresting Systems?

The MUTCD describes vehicle-arresting systems, as portable netting, cables, and energy-absorbing anchors designed to prevent penetration into activity areas while providing for smooth, reasonably safe deceleration for the errant vehicles.

How are Vehicle Arresting Systems Used?

These devices are typically used where sections of a roadway are subject to frequent openings and closings over extended work durations. When an errant vehicle enters a section of closed roadway, the consequences may be extremely severe, because workers do not expect to encounter traffic. This risk may be even higher on nighttime projects. For such situations, the systems may be placed across the entire roadway at the closure point, as well as at any downstream ramps and other potential entrance points to physically prevent errant vehicles from entering the work space. Typically, provisions are necessary to permit construction traffic to bypass the arresting system to enter the work space. In some situations, a watchman or police officer may be stationed at the bypass to prevent unauthorized or unintentional intrusions into the work space.

Work Zone Design Considerations for Vehicle Arresting System Use

Since these devices are designed to slow vehicles gradually and maintain occupant safety, an adequate deceleration distance is needed behind the net (typically at least 120 feet for 60 mph roadways). Because anchor devices need to be installed, vehicle arresting systems are typically used where they will be in use on a daily or nightly basis over an extended period. However, in some cases, anchorage may also be provided for short term applications where a vehicle arresting system is considered desirable for a single or a few work shifts.

References

(1) Positive Protection - Reducing Risk, Protecting Workers and Motorists. Brochure published by the Federal Highway Administration, 2003.

(2) Code of Federal Regulations, Title 23, Part 630, Subpart K – Temporary Traffic Control Devices (FHWA-2006-25203-0081).

(3) Federal Highway Administration, *Manual on Uniform Traffic Control Devices, 2003 Edition* (Washington, DC: 2003).

(4) American Association of State Highway and Transportation Officials, *Roadside Design Guide, 3rd Edition* (Washington, DC: 2002)

(5) Bryden, J. NCHRP 20-7 (174): *Positive Protection Practices in Highway Work Zones*. Transportation Research Board of the National Academies, June 2005. (Available upon request from TRB staff: *http://www.trb.org*).

(6) Ross, H., D. Sicking, and R. Zimmer. *NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features*. Transportation Research Board of the National Academies, 1993.

(7) Marzougui, D., M. Buyuk, and S. Kan. *Performance Evaluation of the Portable Concrete Barriers*. Draft Report, January 2007.

SAFER ROADS SAVE LIVES

American Traffic Safety Services Association

U.S. Department of Transportation
Federal Highway Administration