smooth, sealed outer surface should be used for signs and other traffic control devices. Reflectorized material should meet the agency's specifications for new material.

- *Illuminated* signs should be considered when a reflectorized sign is not effective, as when the sign is overhead or when background light sources reduce the sign's visibility.

2. Markings

Pavement markings are very important in guiding traffic through work zones. Pavement markings and delineators outline the vehicular path to lead traffic around a work area.

Pavement Markings

Drivers use pavement markings as a primary means of guidance. Pavement markings include lane stripes, edge stripes, centerline stripes, pavement arrows and word messages. Markings are made of paint (with bead reflectorization), raised reflectorized markers, preformed adhesive-backed reflectorized tape, cold preformed reflectorized plastics, hot reflectorized plastics, epoxies, and other materials placed by heating and spraying.

The standard markings planned for the road should be in place before opening a new facility to traffic. Also, if revised lane patterns are planned for the work zone, temporary markings should be placed before the traffic is changed. Where this is not feasible, such as during the process of making a traffic shift or carrying traffic through surfacing operations, temporary delineation may be accomplished with lines of traffic cones, other channelizing devices, or strips of adhesive-backed reflectorized tape.

When pavement placed during the day is to be opened to traffic at night and permanent striping cannot be placed before the end of work, a temporary stripe should be applied to provide an indication to the driver of the location of the lane or centerline. Standard marking patterns are most desirable for this use. On rock-screened seal coats, striping should be applied following removal of excess screenings.

For relatively long-term use or when the surface is to be covered later with another layer, reflectorized traffic paint, or preformed adhesive-backed tape, with or without raised pavement markers should be considered. For relatively short-term use,

and when frequent shifts are to be made, adhesive-backed reflectorized tape is useful. Raised pavement markers may be used to form the pavement markings or may be used to supplement marked stripes. High speeds and volumes of traffic may justify raised markers for even comparatively short periods. They are particularly valuable at points of curvature and transition.

Pavement arrows are useful in guiding traffic when the traveled way does not coincide with the configuration of the exposed surface area, such as when the color of the transition pavement is different from the existing pavement. Pavement arrows are especially useful on a two-way, undivided roadway to remind the driver of opposing traffic. TWO-WAY TRAFFIC signs should be used in conjunction with the arrows for the application. The arrows should be completely removed once the two-way traffic condition is no longer needed.

Whenever traffic is shifted from its normal path, whether a lane is closed, lanes are narrowed, or traffic is shifted onto another roadway or a detour, conflicting pavement markings should be removed. Exceptions to this may be made for short-term operations, such as a work zone under flaggers' control, moving or mobile operations. Use of raised pavement markings or removable markings may be economical since they are usually easier to remove when no longer needed.

Delineators

Delineators are reflective units with a minimum dimension of approximately 3 inches. The reflector units can be seen up to 1,000 feet under normal conditions, when reflecting the high beams of a car. The delineator should be installed about 4 feet above the roadway on lightweight posts.

Delineators should not be used alone as channelizing devices in work zones but may be used to supplement these channelizing devices in outlining the correct vehicle path. They are not to be used as a warning device. To be effective, several delineators need to be seen at the same time. The color of the delineator should be the same as the pavement marking that it supplements.

3. Channelizing Devices

Channelizing devices are used to warn and direct traffic away from or around a work area. They also control the flow of traffic when separating two directions of travel. Several types, including barricades, vertical panels, cones, and drums, are shown in Figure 4. Each type has distinct visibility characteristics and advantages.

The MUTCD requires that channelizing devices to be used at night shall be reflectorized with a material having a smooth, sealed outer surface. This includes commercially available reflectorized sheeting and tape strips. All channelizing devices should be a lesser hazard, if struck by an errant vehicle, than the hazard marked.

Some devices require a weight, such as a sand bag, because they are easily knocked or blown over. These weights should be placed at the bottom of the device for stability and to keep the weight from being thrown as a result of collision. Neither the device nor the weight should cause excessive damage when struck by a vehicle. Also, sand bags should not be placed in a way that will limit the motorist's view of the device.

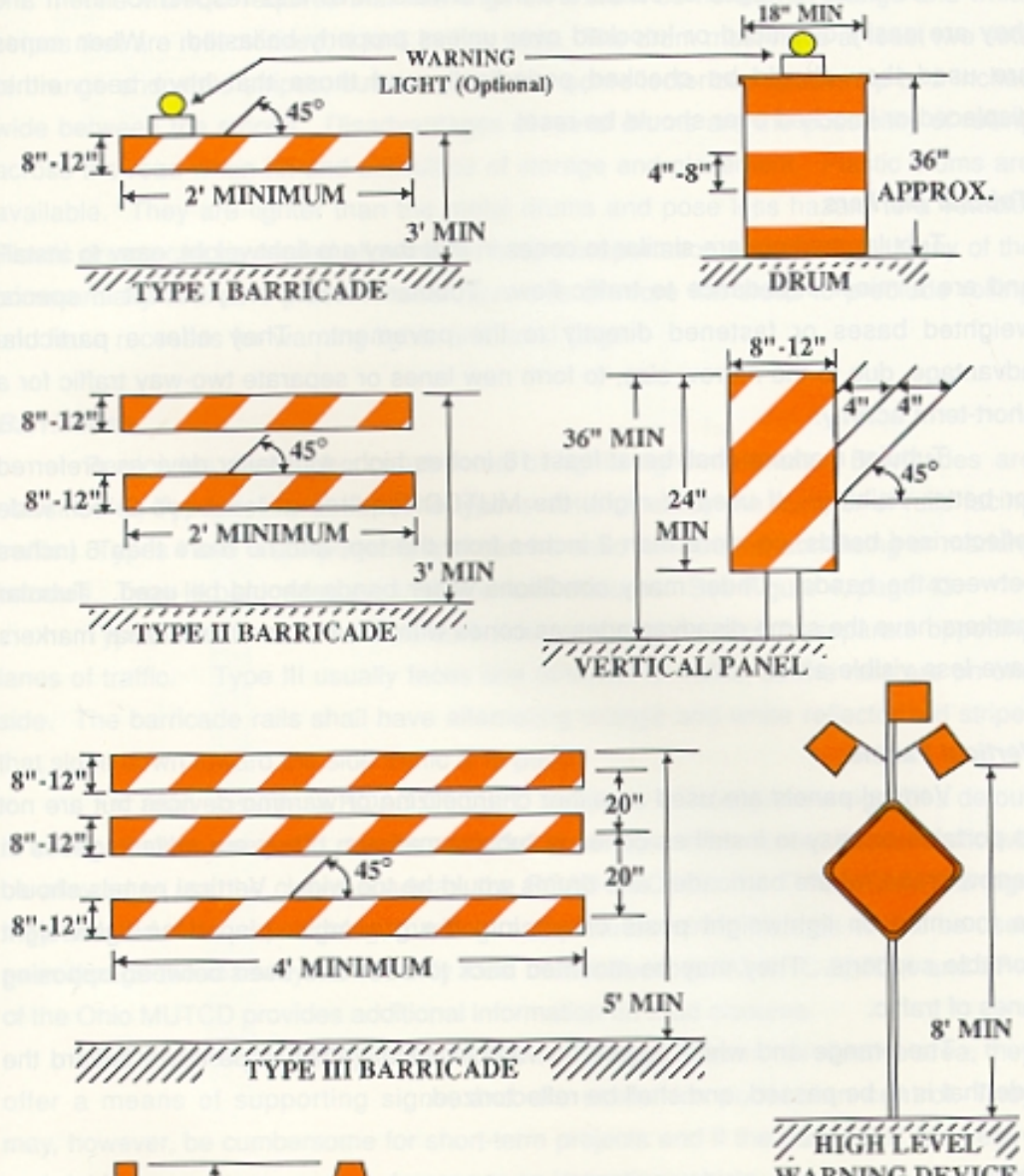
Cones

Cones are lightweight channelizing devices that may be stacked for storage, are easy to place and remove, and are a minor impedance to traffic flow. For stability, a rubber or sand collar or specially weighted base may be added. Cones cause little or no damage when hit. They shall be at least 18 inches high, but taller cones should be used on freeways and other roadways where speeds are relatively high, or wherever more conspicuous guidance is needed. Taller cones (up to 36 inches high) have good daytime visibility.

Cones can be made more effective by:

- Using fluorescent colors (daytime);
- Adding flags (daytime);
- Supplementing with other devices, such as a high-level warning device (daytime);
- Supplementing with flashing arrow panels when lane closures are involved (day and night); and
- Using wider reflectorized bands (night).

CHANNELIZING DEVICES AND HIGH LEVEL WARNING DEVICES



NOTE:
Flashing or steady burn warning lights should be used on barricades, panels, and drums as needed.

Figure 4

If used at night, the MUTCD requires that they be reflectorized with a 6-inch wide reflectorized band, no more than 3 inches from the top, or that they be equipped with a lighting device.

The disadvantages of cones are that drivers have less respect for them and they are easily displaced or knocked over unless properly ballasted. When cones are used they should be checked periodically and those that have been either displaced or knocked over should be reset.

Tubular Markers

Tubular markers are similar to cones in that they are lightweight, easy to install, and are a minor impedance to traffic flow. Tubular markers may be set in special weighted bases or fastened directly to the pavement. They offer a particular advantage, due to the narrow size, to form new lanes or separate two-way traffic for a short-term activity.

Tubular markers shall be at least 18 inches high, with taller devices preferred for better visibility. If used at night, the MUTCD requires at least two 3-inch wide reflectorized bands, no more than 2 inches from the top, and no more than 6 inches between the bands. Under many conditions wider bands should be used. Tubular markers have the same disadvantages as cones with the addition that tubular markers have less visible area.

Vertical Panels

Vertical panels are used as either channelizing or warning devices but are not as portable or easy to install as cones or tubular markers. They are advantageous in narrow areas, where barricades and drums would be too wide. Vertical panels should be mounted on lightweight posts driven into the ground or placed on lightweight portable supports. They may be mounted back to back and used between opposing lanes of traffic.

The orange and white stripes on vertical panels shall slope down toward the side that is to be passed, and shall be reflectorized.

Drums

Drums are used as either channelizing or warning devices. These devices may be highly visible, give the appearance of being formidable objects and, therefore, command the respect of drivers. Due to their size and weight, metal drums are usually limited to longer-term work operations. For stability, a small

amount of sand may be placed in the drum. Where the potential for freezing exists, drain holes should be made in the bottom to permit draining to lessen the hazard if struck by a vehicle.

The MUTCD requires that markings on a drum be horizontal orange and white stripes that are reflectorized, 4 to 8 inches wide. The drum must have at least two sets of orange and white stripes, but can also have nonreflectorized spaces up to 2 inches wide between the stripes. Disadvantages of metal drums are the possibility of rolling across the road when hit and difficulties of storage and placement. Plastic drums are available. They are lighter than the metal drums and pose less hazard to a vehicle. Plastic drums can be nested allowing for easy transportation and storage. Many of the commercially available plastic drums have one or more flat sides to preclude rolling and have recesses for warning lights and sand bags.

Barricades

Barricades should be constructed of lightweight materials. Barricades are classified as Types I, II and III. (The type is determined by the number of rails facing traffic.) Types I and II are portable and can be used for either channelizing or marking hazards. Type III barricades are used for road closures. See Figure 4, page 43.

Types I and II have rails on both sides and may be used to separate opposing lanes of traffic. Type III usually faces one direction of traffic, so the rails are on one side. The barricade rails shall have alternating orange and white reflectorized stripes that slope down toward the side traffic is to pass.

For road closures, a ROAD CLOSED sign, and a Detour Arrow sign, (if a detour is used), shall be used and may be mounted on a Type III barricade. If local traffic will be allowed to use the closed roadway, the ROAD CLOSED TO THRU TRAFFIC sign may be used. Adequate signing, marking, and protection from hazards should be used even though the roadway carries only local traffic. Sections 7C-4, /C-5, 7D-4 and 7F-4 of the Ohio MUTCD provides additional information on road closures.

Barricades may be highly visible due to the large amount of reflective area, they offer a means of supporting signs, and are useful for pedestrian control. They may, however, be cumbersome for short-term projects and if the barricades are heavy and rigid, may cause excessive damage to an impacting vehicle.

Barriers

The terms barrier and barricade are frequently confused. A barricade, as discussed above, is an item that provides a visual indication of a hazardous location or of the desired path a motorist should take. On the other hand, a barrier provides a physical limitation through which a vehicle would not normally pass.

There are four primary functions of barriers:

- Keep traffic from entering a work area or from hitting an exposed object or excavation.
- Provide positive protection for workers.
- Separate two-way traffic.
- Protect construction such as false work for bridges.

Portable roadside barriers are usually made of concrete or metal. They are designed to contain and redirect an errant vehicle. An example is shown in Figure 5. Portable concrete barriers may be precast sections with built-in connecting devices. The connecting devices must be strong enough to insure that the individual elements act as a smooth continuous barrier. For some applications it may be necessary to anchor the concrete barrier to prevent lateral movement if hit by a vehicle. This can be accomplished with drift pins or anchor bolts placed in holes drilled in the pavement or bridge structure.

Barriers may serve the additional function of channelizing traffic. When used as channelizing devices, barriers should be light in color for increased visibility. Delineators or steady-burn warning lights may be attached to the barrier for channelization. A solid edge line may be placed on the pavement adjacent to the barrier.

The need for barriers should be based on an engineering analysis. Portable concrete barriers are designed to minimize damage when they are hit. When a barrier is used in a lane closing situation, the barrier should be preceded with channelizing devices placed along a standard lane closing taper (Figure 12, page 65).

EXAMPLES OF THREE TYPES OF BARRIERS

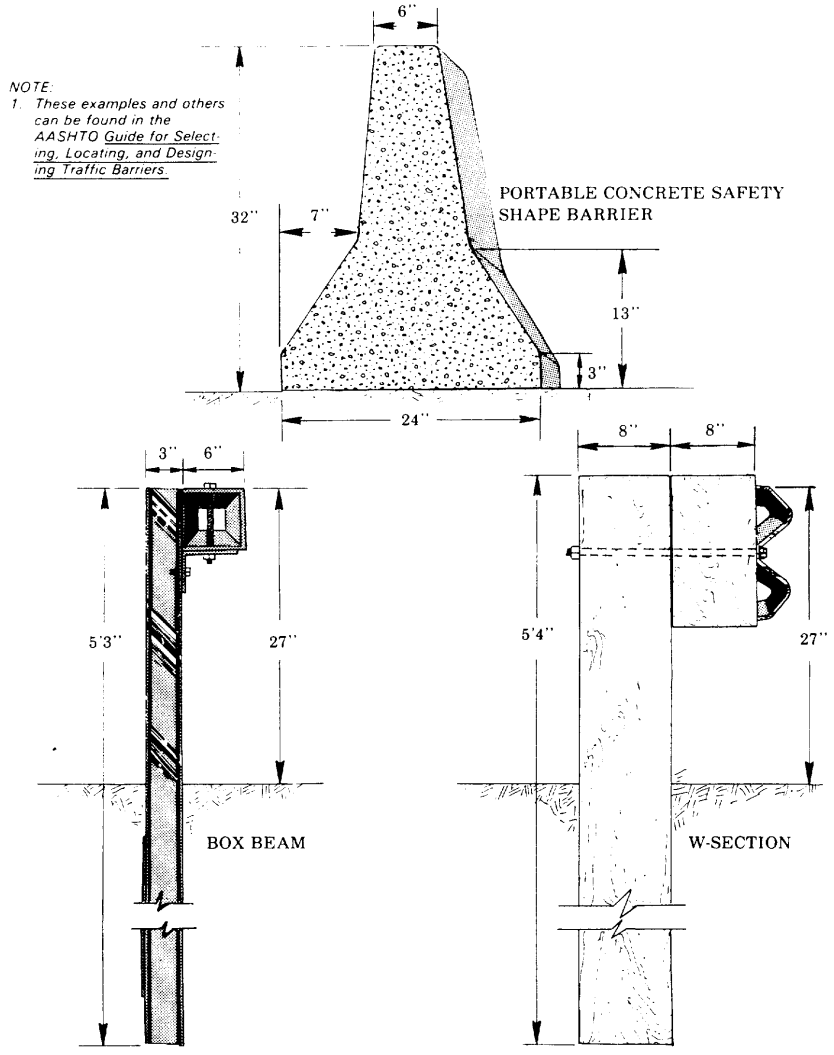


Figure 5

On construction projects, particular attention is needed for connecting portable or temporary barriers to adjacent existing barriers or guardrails. The construction plans should provide details for this. All connections should develop the full strength of the barrier system(s). Also, proper transitions must be used. For additional information see the Guide for Selecting, Locating and Designing Traffic Barriers (List of References #3).

Exposed ends of barriers should have crash cushions to protect traffic. Another way to protect traffic is to flare the ends away from the roadway by extending the barrier beyond the clear roadside recovery area (Figure 12, page 65).

High-Level Warning Devices

High-level warning devices are tall, portable stands with flags and/or flashing lights that are visible above traffic and parked cars. They have three flags, 16-inch square or larger, at least 8 feet above the roadway (Figure 4, page 43).

The devices may be used with flags only, may have a sign or flashing light attached, or may be attached to vehicles used in moving or mobile work operations.

4. Lighting Devices

Warning Lights

Most of the warning lights in use are portable, lens directed, enclosed units and may be used on channelizing devices, barriers, and signs. Detailed discussions on the use and operating requirements of warning lights are contained in Section 7G-6 of the Ohio MUTCD.

The principal types and uses of warning lights are:

- Flashing lights, Type A, are appropriate for use on a channelizing device to warn of an isolated hazard at night or to call attention to warning signs at night;

- High intensity lights, Type B, are appropriate to use on advance warning lights day and night; and

- Steady-burn lights, Type C, are appropriate for use on a series of channelizing devices or on barriers which either form the taper to close a lane or shoulder or keep a section of lane or shoulder closed, and are also appropriate on the channelizing device alongside the work area at night (see Figure 1, page 12).

Warning lights should be secured to the channelizing device or sign in such a way that they will not separate from the channelizing device or sign if impacted by a vehicle. Warning lights that come loose during an accident may become dangerous flying objects.

Flashing Vehicle Lights

Work vehicles in or near the traffic areas are hazards and should be equipped with flashing lights. The vehicle warning lights may be emergency flashers, flashing, strobe, or rotating beacons. High intensity lights are effective both day and night. The laws of the agency having jurisdiction over the street or highway should be be checked concerning requirements for flashing vehicle lights.

These lights should be used in addition to other channelizing and warning devices. However, in some emergency situations, where the work will be in progress for a short time, these lights may be the only warning device.

Flashing Arrow Panels

Arrow panels are signs with a matrix of lights capable of either flashing or sequential displays. Flashing arrow panels are effective day and night, for moving traffic out of a lane to the left, to the right, and may be used for tapered lane closures and moving operations.

These are two types of arrow panels, flashing and sequencing. Flashing arrow panels have three basic operating modes:

- left arrow,
- right arrow, and
- caution mode (four or more lamps arranged in a pattern which does not indicate a direction).

Sequencing arrow panels have several arrowheads that flash in a series, directing traffic to the right or left.

The minimum sizes for arrow panels are shown in Table 5. The flash rate should be between 25 and 40 flashes per minute. The minimum lamp "on time" should be 50 percent for the flashing arrow and 25 percent for the sequential chevron.

ARROW PANEL SIZE AND DIMENSIONS

Type	Minimum Number Minimum Size	Minimum Legibility of Panel Lamps	Distance
A	24" x 48"	12	1/2 mile
B	30" x 54"	13	3/4 mile
C	48" x 96"	15	1 mile

TABLE 5

The flashing or sequencing arrow modes should NOT BE USED under the following conditions:

- When the location of work does not require any lanes to be closed.
- When all of the work is on or outside the shoulder and there is no interference which requires the adjacent traveled lane to be closed.
- When the flagger is controlling traffic on a normal two-lane, two-way road.

Use of the arrow modes under the above conditions will lead to the loss of credibility when the arrow mode is used for lane closures or moving operations.

The caution modes may be used for stationary or moving work operations on or outside of the shoulder. The caution mode may be used in addition to other devices such as signs, channelizing devices, or flashing vehicle lights.

As large arrow panels can be seen from a mile away, they are especially effective in high-volume or high-speed areas and on the work or shadow vehicle for moving operations. For day and night use, arrow panels should be equipped with both an automatic and manual dimming device capable of 50 percent dimming. Flashing arrow panels that are used at night should be checked to insure that the device is properly dimmed; otherwise, motorists may be temporarily blinded. Circular hoods are recommended around each of the lenses to prevent side distraction at night. For more information, see Section 7G-8 of the Ohio MUTCD.

Hazard Identification Beacons

Flashing hazard identification beacons are used in work areas both day and night to alert drivers of a critical point in the highway, such as a truck crossing, and have the same meaning as permanently mounted beacons. Flashing beacons are not used for channelization. Flashing beacons with a yellow lens that is a minimum of 8 inches in diameter are brighter than flashing warning lights, Types A and B. See Sections 7G-3 and 7G-5 of the Ohio MUTCD for additional information.

Floodlights

Floodlights are used to light work activities, flagger stations and other restricted or hazardous areas at night when area lighting is not sufficient. Floodlights should be positioned or shielded to prevent glare to the drivers. The increased visibility provided by floodlighting may enable the driver to see distracting portions of the work area. In this case, steady-burning warning lights mounted on channelizing devices may be advisable. Floodlighting the work area cannot be considered as illuminating signs or devices. Each illuminated sign or device should have its own light source.

During the planning and design of a street improvement project, consideration may be given to specifying that proposed street lighting be completed as one of the earlier stages during construction. Consideration should also be given for providing temporary luminaires at certain locations such as the work activity, certain crossroads, and transitions.

5. Shadow Vehicles

Moving operations, such as lane striping or sweeping, need traffic controls that move with work operations. Shadow vehicles may be used to assist traffic control for moving operations. Signs and other warning devices may be placed

on the work vehicle (depending on the type of work) or the shadow vehicle, or both. Need for a shadow vehicle depends on the speed of traffic compared to the speed of the work vehicle, exposure to traffic of workers and the type of work activity. Portable crash cushions can be attached to the shadow vehicle to protect motorists and workers from a collision. Signs, flags, flashing lights, or arrow panels may be attached to shadow vehicles to warn traffic. Arrow panels may be used on multi-lane highways but should not be used on a two-lane, two-way road.

6. Flagging Procedures

Flagging should only be employed when required to control traffic or when all other methods of traffic control are inadequate to warn and direct drivers.

The procedures for flagging traffic are contained in Sections 7H-2 through 7H-8 of the Ohio MUTCD. Those procedures were developed over a period of time and are workable. The standard signals to be used by flaggers are illustrated in Figure 6. In addition, Figures 13, 14 and 15 (pages 66, 68, and 69) show the proper positioning of the flagger. It should be noted that the figures show the use of channelizing devices to form a lane closure behind the flagger.

Flagger Training

Attention should be given to the proper instruction of all personnel who are flaggers, starting with the basics of flagging. New flaggers should have a special introductory training session and all flaggers need periodic reminders as well as close supervision.

Flaggers need to know the correct ways to stop, slow down, or keep traffic moving. They should also know how to be courteous to the public, to explain delays or to help motorists. Some agencies give the flagger a pocket instruction card that shows the proper methods for controlling traffic.

Flagger Guidelines

Since flaggers are responsible for the safety of traffic and workers, their job is important. They can promote good public relations because they have close public contact. The image they project is often responsible for the public's attitude toward the entire work operation.

USE OF HAND SIGNALING DEVICES BY FLAGGER

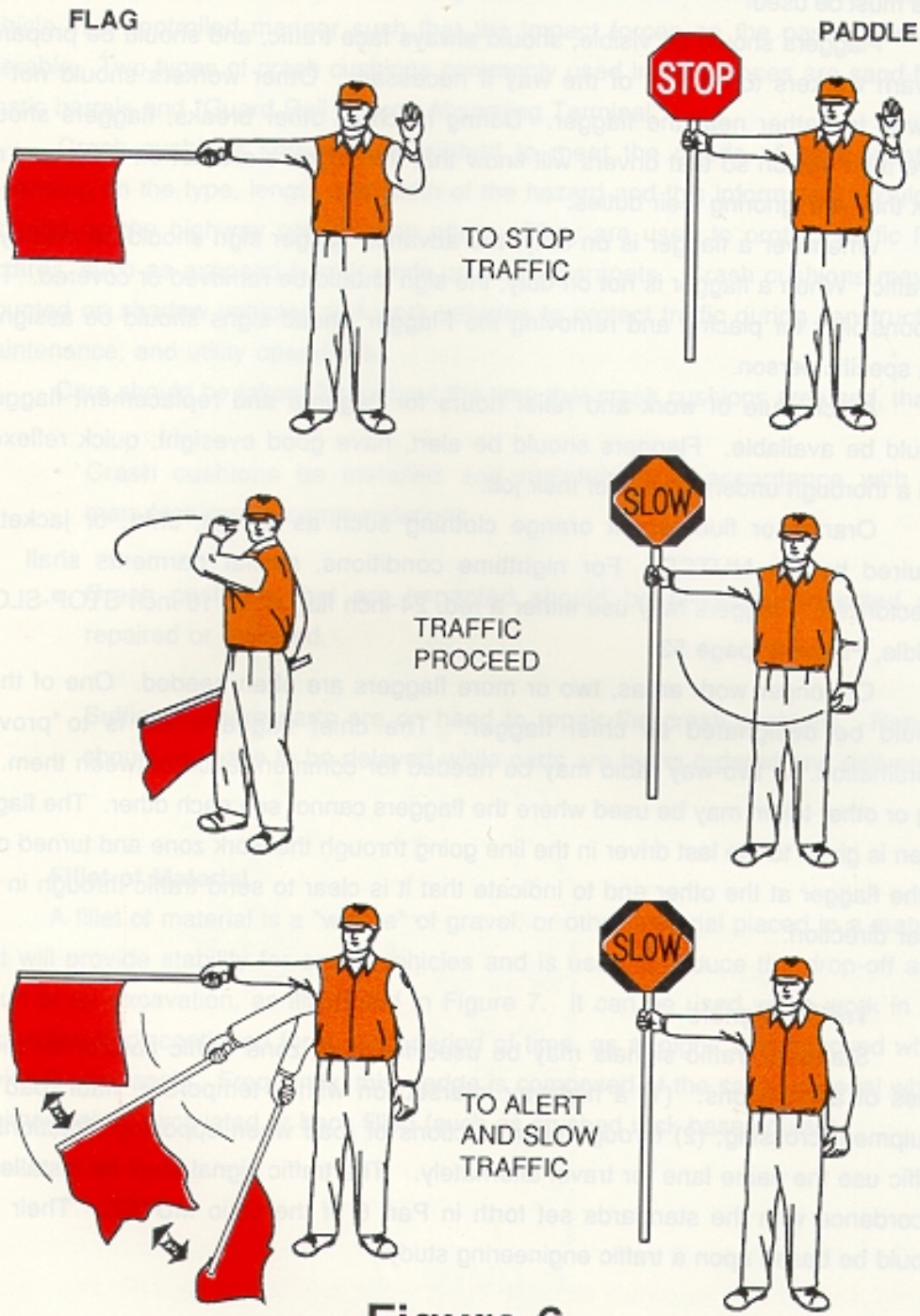


Figure 6

For short work areas where both ends can be seen at the same time one flagger may suffice. Both directions of traffic must be able to see the flagger and to recognize the person as a flagger. If this is not possible with one flagger, then two or more must be used.

Flaggers should be visible, should always face traffic, and should be prepared to warn workers to get out of the way if necessary. Other workers should not be allowed to gather near the flagger. During lunch or other breaks, flaggers should leave their station so that drivers will know that the flaggers are not on duty, and not think they are ignoring their duties.

Whenever a flagger is on duty, the advance flagger sign should be displayed to traffic. When a flagger is not on duty, the sign should be removed or covered. The responsibility for placing and removing the Flagger Ahead signs should be assigned to a specific person.

A schedule of work and relief hours for flaggers and replacement flaggers should be available. Flaggers should be alert, have good eyesight, quick reflexes, and a thorough understanding of their job.

Orange or fluorescent orange clothing such as a vest, shirt, or jacket is required by the MUTCD. For nighttime conditions, similar garments shall be reflectorized. Flaggers may use either a red, 24-inch flag or an 18-inch STOP-SLOW paddle, Figure 6, page 53.

On longer work areas, two or more flaggers are often needed. One of them should be designated as chief flagger. The chief flagger's job is to provide coordination. A two-way radio may be needed for communication between them. A flag or other token may be used where the flaggers cannot see each other. The flag or token is given to the last driver in the line going through the work zone and turned over to the flagger at the other end to indicate that it is clear to send traffic through in the other direction.

7. Traffic Signals

Standard traffic signals may be used for work zone traffic control for these types of applications: (1) a highway intersection with a temporary "haul road" or equipment crossing; (2) through short sections of road when opposing directions of traffic use the same lane for travel alternately. The traffic signal shall be installed in accordance with the standards set forth in Part 6 of the Ohio MUTCD. Their use should be based upon a traffic engineering study.

8. Miscellaneous

Crash Cushions

Crash cushions are devices designed to absorb the energy of an impacting vehicle in a controlled manner such that the impact forces on the passengers are tolerable. Two types of crash cushions commonly used in work zones are sand-filled plastic barrels and "Guard Rail Energy Absorbing Terminal."

Crash cushions should be designed to meet the needs of each location, depending on the type, length and width of the hazard and this information should be included on the highway construction plans. They are used to protect traffic from hazards, such as exposed barrier ends or bridge parapets. Crash cushions may be mounted on shadow vehicles and work vehicles to protect traffic during construction, maintenance, and utility operations.

Care should be taken, throughout the time that crash cushions are used, that:

- Crash cushions be installed and maintained in accordance with the manufacturers' recommendations.

- Crash cushions that are impacted should be promptly inspected and repaired or replaced.

- Sufficient spare parts are on hand to repair the crash cushions. Repairs should not have to be delayed while parts are being ordered and delivered.

9. Fillet of Material

A fillet of material is a "wedge" of gravel, or other material placed in a manner that will provide stability for errant vehicles and is used to reduce the drop-off as a result of an excavation, as illustrated in Figure 7. It can be used when work in the excavation is discontinued for a short period of time, as at night, and removed when work will start again. Frequently, this wedge is composed of the same material which is either being excavated or back filled (such as crushed rock base course).

CROSS SECTION VIEW OF A MATERIAL FILLET

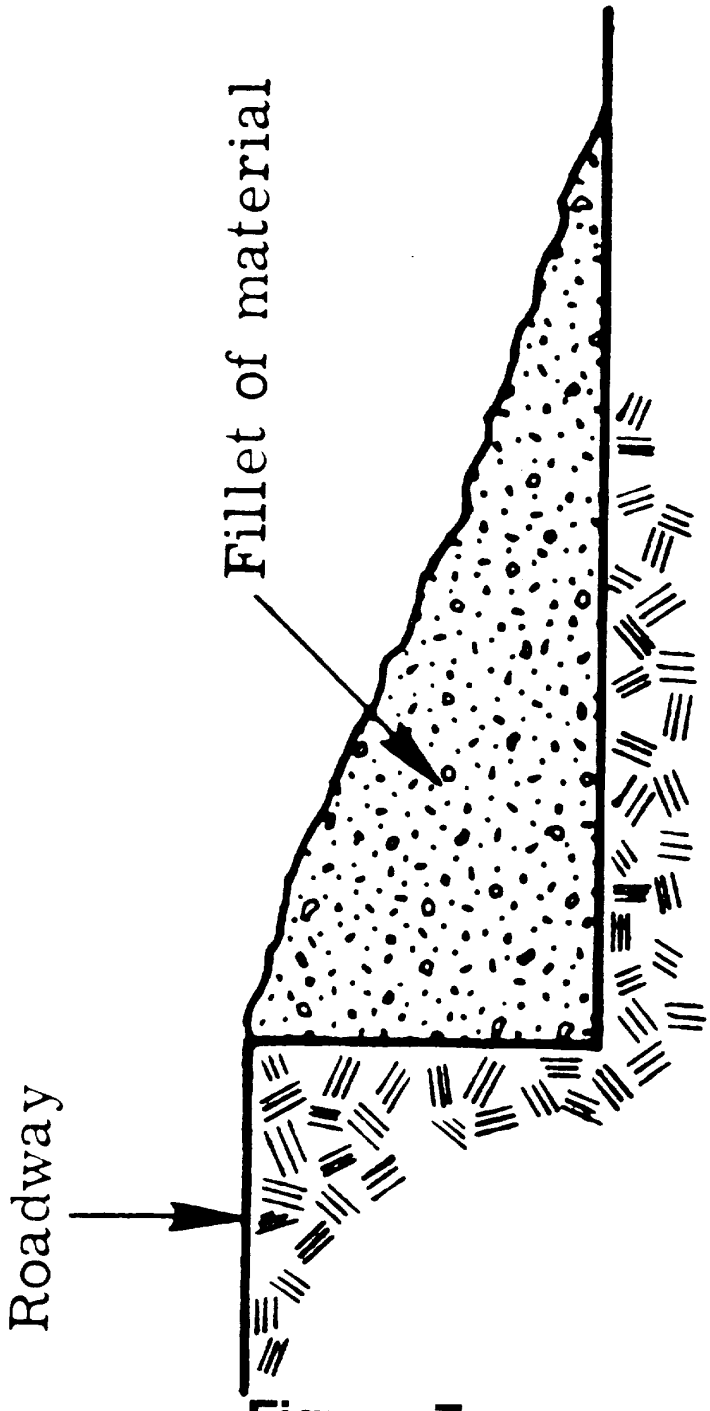


Figure 7

10. Variable Message Signs

Portable variable message sign devices capable of displaying various messages to the motorist will sometimes facilitate construction zone signing. These devices are normally trailer or truck mounted and have their own power system. As they are expensive to buy and operate variable message signs are normally used for the more complex traffic control plans.

Messages, or series of messages, can be preprogrammed into the device or can be added with an additional memory device. Some variable message signs can be programed in the field. Display panels may have one, two, or three lines of copy.

When using a variable message sign care should be taken to insure that the message is clear. A lengthy message may distract the motorist from his driving task for too long a time. The sequencing of the words in a message can also cause problems. For example, RIGHT LANE CLOSED MERGE would get a different driver response than LANE CLOSED MERGE RIGHT. Yet, the messages are similar except for the beginning point.

Variable message signs are especially useful in the following situations:

- When different messages are needed during the day due to changing work operations.
- For upstream traffic diversion when instructions vary with traffic conditions.
- For emergency conditions.

D. Typical Applications (Layouts)

Each traffic control zone is different, with variables such as speed, volume, location of work, pedestrians, and intersections changing the needs for each location. The goal of a traffic control zone is safety, and the key factor in making the control zone work is the application of proper judgment. The examples in this chapter are guides showing how to apply the standards.

Typical applications include the use of various traffic control methods, although they do not include a layout for every conceivable work situation. Typical applications may be altered to fit the conditions of a particular work area.

The layouts in the MUTCD and this Handbook represent minimum requirements. Other devices may be added to supplement the devices shown in the layout, and sign spacings and taper lengths can be increased to provide additional